NO-TILL VERSUS TILLED DRYLAND COTTON, GRAIN SORGHUM, AND WHEAT, AND BREAKEVEN PASTURE LEASE RATE FOR DUAL-PURPOSE WINTER WHEAT

By

BRANDON THOMAS VARNER

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Thesis Approved:

Francis Epplin

Thesis Adviser

Raymond Joe Schatzer

Damona Doye

Sheryl A. Tucker

Dean of the Graduate College

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PAPER I

Economics of No-Till versus Tilled Dryland Cotton, Grain Sorghum, and Wheat [1]

Abstract

The majority of cropland in the Southwest Oklahoma Agricultural Statistics District is tilled and seeded to continuous monoculture winter wheat (*Triticum aestivum* L.). This study was conducted to determine the expected yield and expected net returns of wheat, cotton (*Gossypium hirsutum* L.), and grain sorghum (*Sorghum bicolor* L. Moench), under two production systems, no-till (NT) and tilled (TL), and to determine the most risk-efficient system. The effect of tillage was investigated over six years at Altus, OK, on a Hollister silty clay loam (fine, smectitic, thermic Typic Haplusterts) soil. Wheat and cotton yields were not different between tillage systems. Sorghum NT yielded significantly more than TL sorghum ($P \leq 0.05$). Wheat NT produced the greatest expected net return to land, labor, overhead, and management (\$217 ha^{-1} yr^{-1}). Tilled grain sorghum was the least profitable system (-\$42 $ha^{-1}yr^{-1}$). Wheat NT required additional expenditures for herbicides (\$15 ha^{-1}), less for machinery fuel, lube, and repairs (\$22 ha^{-1}), and less (\$23 ha^{-1}) for machinery fixed costs. Net returns were slightly

[1] This paper was published in the *Agronomy Journal*. It is included in this thesis as it appears in the *Agronomy Journal* 103(2011):1329-1338. The assistance of Mr. Gary Strickland who conducted the field experiments is gratefully acknowledged.

greater ($18 ha^{-1}) for NT wheat than for TL wheat. However, since NT wheat yields were more variable, TL wheat may be preferred by risk-averse producers. Estimated machinery labor savings from switching from TL to NT wheat were 0.588 hours ha^{-1} or 609 hours yr^{-1} for a 1036 ha farm. The decision to switch from TL to NT wheat depends on risk preferences, and on the potential to use saved labor productively elsewhere, or to farm more land.

Introduction

The use of no-till (NT) for crop production in the Southwest Oklahoma Agricultural Statistics District (District) (Caddo, Comanche, Cotton, Greer, Harmon, Jackson, Kiowa, and Tillman counties) is low compared to the national average. Based on data reported by the Conservation Technology Information Center (CTIC), in 2004 NT was used on less than six percent of the annually cropped land in the CTIC region that includes the Southwest Oklahoma Agricultural Statistics District. This usage is less than one-quarter of the national average of 22.6 % (CTIC, 2004). The CTIC (2006, p. 9) categorizes tillage systems that involve full-width tillage, from one up to 15 tillage passes that result in less than 15 percent of the soil surface covered by residue after planting as either intensive-till or conventional-till (TL).

For many years prior to 1996, federal policy provided incentives for District producers to grow continuous wheat (*Triticum aestivum* L.) and disincentives to diversify (Biermacher et al., 2006). In 1996, the Federal Agriculture Improvement and Reform Act (Freedom to Farm Act) provided a major departure from prior federal policy. The incentive to build and maintain wheat program base was removed and farmers were free to try other crops on wheat base land, without jeopardizing federal subsidies. From 1977-

1996 an average of 81% of the dryland area cropped in the District was seeded to winter wheat (Fig. I-1) (USDA-NASS, 2010). In the decade after the 1996 (1997-2007) legislation, wheat was seeded on an average of 86% of the dryland area cropped in the District. By this measure, cropping patterns in the District did not change in response to the 1996 freedom to farm legislation.

Based on the revealed production patterns, it could be inferred that farmers expect wheat to be the most economical dryland production alternative in the District. The chart in Fig. I-2 illustrates the percentage of wheat, cotton (*Gossypium hirsutum* L.), and grain sorghum (*Sorghum bicolor* L. Moench) planted area that was not harvested over the decade from 1998 to 2007. During the decade, 34% of the land planted to dryland grain sorghum in the District was not harvested for grain (Fig. I-2). Similarly, 32% of the land planted to cotton was not harvested for lint (Fig. I-2). In 2000 and 2006 more than 70% of the area planted to dryland cotton was abandoned. In 2004, 2005, and 2007 less than 10% of the area planted to dryland cotton was abandoned. This variability in the proportion of area planted that was not harvested is a consequence of the District's highly variable weather and growing conditions. One advantage that wheat has relative to cotton, is that wheat has multiple uses (Decker et al., 2009). Even though 36% of the wheat area planted from 1998 to 2007 in the District was not harvested for grain, it may have generated some income by producing forage for livestock.

Previous tillage studies conducted outside the District have reported inconsistent results for yield differences between NT and TL systems (Bordovsky et al., 1998; Clark et al., 1996; Jones and Popham, 1997). Some studies have found no difference in yields across tillage system. Other studies have found greater yields with NT and some studies have found that NT resulted in lower yields. Toliver et al. (2011) evaluated results from 442 tillage experiments conducted at 92 locations across the U.S. They found that yield differences between NT and tilled plots depend on the crop grown, soil type, region, rainfall, and technology available and used when the experiment was conducted.

No studies of the consequences of alternative tillage systems for continuous wheat, grain sorghum, and cotton production have been conducted in the District. However, some experiments have been conducted elsewhere in the Southern Plains. When wheat is grown year after year in the same field, grain yield is often reduced when a substantial quantity of wheat residue from the previous wheat crop is retained on the surface (Daniel et al., 1956; Zingg and Whitfield, 1957; Harper, 1960; Davidson and Santelmann, 1973; Heer and Krenzer, 1989; Epplin et al., 1994; Epplin and Al-Sakkaf, 1995; Decker et al., 2009). The studies have not provided definitive reasons for lower yields for continuously cropped NT wheat relative to TL wheat. There are several potential causes. Weed species that are adapted to the environment may flourish and become difficult to control in a continuous cropping system. Furthermore, if wheat crop residue is retained on the soil surface, disease organisms may bridge from old crop residue to the new crop (Biermacher et al., 2006).

Heer and Krenzer (1989) conducted a four year study of continuous wheat in which they compared conventional tillage with NT at two Oklahoma locations. They found that the use of NT increased the spring profile soil water but found that the additional soil water did not result in greater yields. Economic analysis revealed that the conventional tillage system was more economical (Heer and Krenzer, 1989; Epplin et al., 1993).

Yield differences between TL and NT cotton experiments have not been consistent. Segarra et al. (1991) conducted a study several hundred km west of the District and found that NT cotton yields were greater than TL yields. However, Bordovsky et al. (1994) who conducted a similar study in a different region on different soils in the Southern Plains found no differences between NT and TL cotton yields. The differences in results across studies at different locations tend to confirm Toliver et al.'s (2011) conclusion that yield differences between NT and TL depend on a number of location specific factors such as soil type and rainfall.

Yield results for experiments comparing NT to TL grain sorghum also differ across studies. For example, Baumhardt et al. (1985) found greater yields for NT whereas Williams et al. (2000) found greater yields for tilled grain sorghum. These differences in results across studies at different locations provide justification for basing recommendations to farmers on studies conducted as near as possible to represent local conditions.

A comprehensive evaluation of the economics of NT relative to TL requires information regarding differences in expected yields, input requirements, machinery fixed costs, and machinery operating costs. In general, machinery fixed and operating costs are lower for NT (Epplin et al., 1982). However, the expenditures for herbicides are usually greater for NT. No-till requires less labor for operating machines, but the value of the labor is farm specific in that it depends on whether or not it can be put to productive use elsewhere.

This study was conducted to determine the expected yield and expected net returns for each of the three major crops grown in the District, cotton, wheat, and grain sorghum, under two tillage systems, NT and TL, and to determine the most risk-efficient system defined as the system that maximizes expected utility. For a risk-neutral producer, defined as one not concerned about year-to-year variability in net returns, the risk-efficient crop and tillage system is the one that maximizes expected net return. For a risk-averse producer who cares about year-to-year variability as well as expected net return, the risk-efficient crop and tillage system is the one that maximizes expected utility which depends on the producer's level of risk aversion.

Materials and Methods

Yield data were produced in a six-year experiment in which each of the three crops was grown under both tillage systems. Machinery complements were designed and production costs were estimated for a 1,036 ha farm. Enterprise budgets were prepared to determine the net return for each crop and each tillage system for each year for which yield data were produced. Net returns distributions were constructed and used to determine the preferred strategy for risk-neutral and risk-averse producers.

Agronomic

The experiment was conducted at the Southwest Research and Extension Center near Altus, OK from 2003 to 2008 (34^{o} 38' N, 99^{o} 20' W) on a Hollister silty clay loam (fine, smectitic, thermic Typic Haplusterts) soil in a dryland environment (Natural Resource Conservation Service, 2010). The experiment was designed as a randomized complete block with split plots with three replications. The plots were 9.1 m by 22.9 m. The tillage treatments (TL and NT) were the main experimental units with crops (continuous cotton, continuous wheat, and continuous grain sorghum) as the sub-units. Field operations including tillage, fertilization, planting, and harvesting for each of the three species and both tillage systems are listed in Table I-1. Operations used for the TL systems are typical of those used in the region.

Seedbed preparation for TL cotton included primary tillage using a chisel plow followed by a disking in March. The NT plots were not tilled at any time during the six-year period. In May, nitrogen (N) was applied as ammonium nitrate at a rate of 112 kg N ha^{-1}. For the TL plots, trifluralin (2,6-dinitro-N,N-dipropyl-4-(trifluoromethyl) benzenamine) was applied in May at a rate of 1.75 L ha^{-1} and incorporated with a field cultivator. Plots seeded to NT cotton were sprayed with glyphosate (N-(phosphonylmethyl)-glycine) (480 g L^{-1} a.i.) during the fallow season at a rate of 2.34 L ha^{-1}. Glyphosate-tolerant cotton, variety Fiber Max 9058F, was planted at a rate of 7.5 seeds m^{-1} of row set on 1.02 m rows. A conventional planter was used for the TL plots and a no-till planter for the NT plots. In June, after weeds had emerged, glyphosate (660 g L^{-1} a.i.) and s-metolachlor (Acetamide, 2-chloro-N-(2-ethyl-6-methylphenyl)-N-(2-methoxy-1-methylethyl]-,(S)) were applied to the TL plots at a rate of 1.6 L ha^{-1} and 1.17 L ha^{-1}, respectively. For the NT plots, glyphosate (660 g L^{-1} a.i.) was applied after planting at a rate of 1.6 L ha^{-1} and a second application of glyphosate (660 g L^{-1} a.i.) was applied in late June. In October, cotton was defoliated with thidiazuron-diuron (N-phenyl-N'-1,2,3-thidiazol-5-ylurea; 3-(3,4-dichlorophenyl)-1,1-dimethylurea) at a rate of 0.82 L ha^{-1} and harvested after all bolls had opened. Cotton stalks were rotary mowed after harvest.

Land seeded to TL wheat was chisel plowed after harvest in June followed by two passes with a disk in June and July. Land seeded to NT wheat was not tilled but was sprayed with glyphosate (480 g L^{-1} a.i.) during the fallow season in June and July at a rate of 2.34 L ha^{-1}. In August, ammonium nitrate at a rate of 140 kg N ha^{-1} was applied. In October, wheat was planted at a rate of 101 kg ha^{-1}. A conventional drill was used for the TL plots and a no-till drill for the NT plots. Plots were seeded with the variety Jagalene except for the last year when OK Bullet was used. In one of the six years sulfosulfuron (1-(2-ethylsulfonylimidazol [1,2-a] pyridin-3-yl-sulfonyl)-3-(4,6-dimethoxy-2-pyrimidinyl) urea) herbicide was applied at a rate of 46.9 g ha^{-1} in November primarily to control perennial grasses. Wheat was harvested in late May or early June.

Land seeded to NT grain sorghum was sprayed with glyphosate (480 g L^{-1} a.i.) during the fallow period at a rate of 2.34 L ha^{-1}. In March, s-metolachlor was tank mixed with glyphosate and applied at a rate of 1.55 L ha^{-1} and 2.34 L ha^{-1}, respectively to the NT plots. Land seeded to TL grain sorghum was chisel plowed in March followed by a disking. In April, ammonium nitrate at a rate of 112 kg N ha^{-1} was applied. Grain sorghum was planted in late April at a rate of 2.24 kg ha^{-1} on 1.02 m rows. A conventional planter was used for the TL plots and a no-till planter for the NT plots. In one of the six years, after the sorghum had emerged, atrazine (2-chloro-4-ethylamine-6-isoproylamino-s-triazine) herbicide was applied at a rate of 2.8 L ha^{-1}. Also in one of the six years, basagran (3-{1-melhylethyl)-1h-2,1,3-benzothiadiazin-4(3h)-one 2.2-dioxide) herbicide was applied to the TL plots in May at a rate of 1.75 L ha^{-1}. Grain sorghum was harvested in September, and stalks were rotary mowed after harvest. In one of the six years, paraquat (1,1'-dimethyl-4,4'-bipyridinium dichloride) was applied to the NT plots at a rate of 4.09 L ha^{-1} to burn down weeds after harvest. Stalks were rotary mowed each year after harvest.

Yield data were analyzed using the mixed model procedure in SAS (PROC MIXED) (Littell et al., 1996; Piepho et al., 2003). The PROC MIXED procedure was used because it recognizes and accounts for year effects (year-to-year variability) as random. It also accounts for the repeated measures (same treatment on a plot across years) aspects of the data (Littell et al., 1996).

Economics

A representative farm approach was used to estimate production costs. A farm size estimate was required to determine the machinery complement. Key and Roberts (2007) reported that the fastest growing farm size group between1982 and 2002 was for farms between 405 and 4047 ha and that farms in this size range farmed 42% of the area. Decker et al. (2009) reported that a farm size of 1036 ha, equivalent to four sections of land, was sufficient to achieve economies of size on Oklahoma wheat farms. Machinery complements were constructed for a farm size of 1036 ha.

Field operations budgeted for both tillage systems and each of the three crops are described in Table I-1. Meteorological data and a field work day simulator originally developed by Reinschmiedt (1973) were used to produce estimates of field work days. Historic rainfall data were used to generate cumulative density functions of the number of days field work could be conducted during each of 24 half-month periods. The 85% probability level was chosen such that machines were sized to accomplish the required work in the appropriate time period in 17 of 20 years. Candidate machines were selected based on farm size, estimated field work days, machines available, required field operations, and a 10 hour work day (Reinschmiedt, 1973; Kletke and Sestak, 1991; Epplin et al., 1993; Decker et al., 2009).

Nine tractor sizes were considered: 71, 78, 93, 101, 116, 127, 160, 190, and 242 kW. Tractors were matched to implements based on implement width. The maximum implement width for a tractor is a function of tractor size, draft, and field speed. For example, nine chisel plows varying in width from 4.6 m to 11.3 m were used as possible candidates. The MACHSEL spreadsheet program was used to find a combination of machines that can complete the specified field operations in the available number of field days (Kletke and Sestak, 1991; Epplin et al., 1993; Decker et al., 2009). The spreadsheet user is required to describe the required field operations and timing of operations; prepare a list of candidate machines with prices and capacities; and enter the expected number of field work days during each two-week period. The user begins with a set of candidate machines, and the program determines the expected operating (fuel, oil, lubricants, repairs) and fixed costs (depreciation, interest on average investment, taxes, and insurance) and determines whether the selected machines can complete the required field operations during the available field work days. The user is required to manually iterate the candidate machines until a set is found that can complete the required field operations in the available time. Machines identified and selected for budgeting for the continuous wheat, continuous cotton, and continuous grain sorghum farms are listed in Tables I-2, I-3, and I-4, respectively. Wheat is the dominant crop in the region, and most wheat in the region is custom harvested. Hence, custom harvesting was assumed for each of the three crops and the machinery complements do not include harvest machines.

Enterprise budgeting was used to compute expected net returns to land, labor, and management for each crop and each tillage system (American Agricultural Economics Association, 2000). Estimated revenue for each cropping system was determined by multiplying the respective yield for each system by the average price received during the 2003-2008 marketing years. Average annual crop prices received for cotton, wheat, and grain sorghum from 2003-2008 were retrieved from the USDA's Oklahoma Agricultural Statistics 2009 annual report (USDA-NASS, 2009). Seed, fertilizer, and herbicide prices were obtained from dealers and distributors in the region. Custom harvesting rates were based on surveys conducted and reported by Doye and Sahs (2009).

For budgeting purposes, it was assumed that N was applied as anhydrous ammonia (NH_3). Anhydrous ammonia costs less and is more commonly used in the region than alternative sources of N, and Grandy et al. (2006) contend that surface applied liquid urea ammonium nitrate can be less available in NT systems due to greater ammonia volatilization. Typically the cost per unit N from NH_3 is 66% of that of liquid nitrogen solutions. For producers who operate farms of 1036 ha this cost savings is more than sufficient to offset the additional application cost. A chisel plow equipped with NH_3 sweeps was budgeted for the TL treatments and a NT NH_3 applicator for the NT treatments.

Distributions of net returns can be constructed from the annual observations available for each of the six production systems. By assuming that the time period of the study represents the entire distribution and by assuming that each of the years is equally likely to occur, stochastic efficiency with respect to a function (SERF) can be used to order the six production alternatives in terms of certainty equivalents and to determine risk premiums (Hardaker et al., 2004; Meyer et al., 2009; Archer and Reicosky, 2009; Hardaker and Lien, 2010; Williams et al., 2010). Stochastic efficiency with respect to a function assumes that decision makers (producers) have utility functions that exhibit constant absolute risk aversion (Meyer et al., 2009). Under this assumption, managers view a risky strategy for a specific level of risk aversion the same without regard for their level of wealth. In practice, a negative exponential utility function is frequently used since it conveniently imposes constant absolute risk aversion across all levels of income and can be used as a reasonable approximation of risk-averting behavior (Babcock et al., 1993; Hardaker et al., 2004; Williams et al., 2010). Stochastic efficiency with respect to a function can be used to calculate certainty equivalents, which enables ranking production alternatives for a given level of risk aversion. The difference between certainty equivalents of any two alternatives is defined as the risk premium. The risk premium is a monetary estimate of the minimum amount that a decision maker would have to be paid to switch from the production alternative with the greater certainty equivalent to the alternative with the lesser certainty equivalent. For a risk-neutral decision maker, the risk premium between any two choices is the difference in expected or mean net returns of the two systems. For example, if a decision maker is risk-neutral (doesn't care about year-to-year variability in net returns) and if the average net return over a number of production seasons is \$110 ha^{-1} for system A, but only \$100 ha^{-1} for system B, the risk premium, or minimum amount that the decision maker would be willing to accept to switch from system A to system B is \$10 ha^{-1} yr^{-1}. The spreadsheet add-in SIMETAR may be used to conduct SERF analysis (Richardson et al., 2001).

Results

Agronomic

Monthly and annual precipitation recorded near the site during the study are provided in Table I-5 (Oklahoma Mesonet, 2010). Precipitation was highly variable across years and across months within years. Monthly totals for June averaged 116 mm, but ranged from 3 mm in 2006 to 240 mm in 2004. Monthly totals for May averaged 56 mm, but ranged from 1 mm in 2004 to 109 mm in 2005. Annual totals averaged 588 mm, but ranged from 473 mm in 2003 to 888 mm in 2004.

Average yields by year for each crop and tillage system are reported in Table I-6. Since the wheat planted in 2003 was not harvested until 2004, only five years of data were available for wheat. Birds destroyed the 2003 grain sorghum plots and the 2003 grain sorghum results are not included in the statistical analysis. When large fields are planted to grain sorghum in a region that includes many fields of grain sorghum, birds do not cause major problems for any one field and minor losses may be incurred across the entire region. However, there were no large commercial fields of grain sorghum located near the experiment. The plots were located several hundred meters from a line of evergreen trees that were planted to serve as a windbreak on the naturally treeless plain. The trees provided shelter for birds and in 2003 when the grain sorghum was ripe, the birds ate the crop. After 2003, measures were taken to address the problem. A bird guard sound system that emits random distressed bird sounds and predator bird calls was put into place. In addition, bird mesh netting covering the actual harvestable yield area was used. These measures in conjunction with harvesting at the earliest possible date were used to manage the problem. It was assumed that losses to birds would be negligible if the crop was grown on a commercial scale. The cost of the bird guard sound system and the cost of the netting was not included in the economic analysis.

All crops in the region suffered from limited precipitation during the 2006 growing season. Over the time period from April through August of 2006, the plots received a total of 191 mm of precipitation (Table I-5). This amount was 51% of the April through August precipitation received during the other five years. In 2006, only 34% of the cotton planted and 37% of the 2006-07 wheat crop planted in the county where the plots were located were harvested (USDA-NASS, 2010). On average, over the time period of the study, excluding 2006, 87% of the land planted to cotton and 80% of the land planted to wheat in the county were harvested (NASS, 2010). The NT grain sorghum plots were harvested in 2006 and produced 89% of the mean yield. However, as a result of the dry weather, the TL plots were not harvested.

The Palmer Drought Severity Index (PDSI) provides an aggregate measure of conditions for crop growth. Historical PDSI values for the District for each year of the study are reported in Table I-5. A PDSI value of 0 is regarded as normal. Values of -2 indicate a moderate drought, -3 a severe drought, and -4 an extreme drought. Similarly, values of +2, +3, and +4 reflect moderate, severe, and extreme wetness (U.S. Department of Commerce, 2011). Historical PDSI values for the Southwest Oklahoma District are available from 1895 through 2010. Over this 116 year period annual values of less than a -2 occurred 18% of the time with values in excess of +2 occurring 25% of the time. For the five years for which data are available for each crop, one year (2006), 20% of the distribution, the PDSI value was below -2, and one year (2005) the value was greater than a +2 (Table I-5). By this measure, the five years of the study for which data are available for each crop are reasonably close to the historical distribution of weather.

Wheat yields, cotton lint yields, and cotton seed yields were not different between TL and NT (Table I-6). Grain sorghum NT yields that averaged 3616 kg ha^{-1} were greater ($P \leq 0.05$) than the TL sorghum yields that averaged 2597 kg ha^{-1}. In four of the five years, NT sorghum produced a greater yield than TL sorghum. If the 2006 season when the TL sorghum had a zero yield is not considered, the mean yield for NT sorghum exceeded the mean yield for TL sorghum by 472 kg ha^{-1}.

Economics

Total revenue, total operating costs, machinery fixed costs, and net returns to land, labor, overhead, and management for each crop and both production systems are reported in Table I-7. The average annual net return from NT wheat was \$208 ha^{-1} followed in order by TL wheat at \$197 ha^{-1}, NT grain sorghum at \$123 ha^{-1}, NT cotton at \$79 ha^{-1}, TL cotton at -\$9 ha^{-1}, and TL grain sorghum at -\$47 ha^{-1}. These greater net returns for wheat than sorghum or cotton could explain why the vast majority of cropland in the District is seeded to continuous wheat. The estimated advantage for NT wheat relative to TL wheat may be insufficient to entice growers to change machinery and invest in learning a new system.

Net returns to land, labor, overhead, and management for each crop and production system by year are reported in Table I-8. Wheat in both tillage systems provided positive net returns in four of the five years and was more consistent at producing positive net returns than either cotton or grain sorghum. Cotton NT produced positive net returns in only two of six years. Grain sorghum NT produced positive net returns in four of five years. In three of the five years for which both NT cotton and NT grain sorghum data were available, NT cotton produced greater net returns than NT grain sorghum. However on average, the net returns for NT grain sorghum exceeded those for NT cotton by \$44 ha^{-1}.

The findings illustrate that the economics of NT relative to TL differ across crops. The expected economic benefits of NT relative to TL are substantially greater for sorghum than for wheat. This is a result of several factors. First, the yield of NT sorghum was significantly greater than the yield of TL sorghum and added 39% to revenue. Wheat NT did not produce significantly more revenue. Second, machinery fixed costs savings are relatively greater for cotton and sorghum that require a NT planter relative to wheat that requires a NT drill or air seeder. The budgeted NT seeder cost $14,000 more than a conventional seeder whereas the NT planter costs only $7,000 more than a conventional planter.

One benefit that NT had for each crop relative to TL was that NT required less machinery time in the field. The estimated pre-harvest machinery labor in hours ha^{-1} for cotton, wheat and grain sorghum, respectively, for each tillage system are reported in Tables I-2, I-3, and I-4. Tilled cotton required an estimated 1448 hours yr^{-1} of machinery labor to farm the 1036 ha., while NT cotton required an estimated 762 hours yr^{-1} of machinery labor for the same farm size, which is a savings of 686 hours yr^{-1}. Wheat NT had an estimated labor savings of 609 hours yr^{-1} on the 1036 ha wheat farm, and NT grain sorghum had an estimated labor savings of 287 hours yr^{-1}. If the labor saved by switching to NT can be used productively elsewhere or if the labor saved enables the producer to farm more land, NT could be the better alternative.

These expected differences in net returns between NT and TL provide an incentive for cotton and grain sorghum producers to adopt NT for cotton and grain sorghum. However, the incentive to adopt NT for continuous wheat is small. By these measures, the rate of adoption for wheat producers could be expected to be slower.

However, NT wheat will require less machinery time ha^{-1} and for producers who have alternative uses for their labor, NT may be the preferred alternative. The value of the labor saved by NT could explain why some wheat producers have adopted NT and others have not done so.

Results of the SERF analysis are reported in Table I-9 that includes net return certainty equivalents for each of the six systems for each of six constant absolute risk aversion coefficients (ARAC). The certainty equivalents for the risk-neutral (ARAC = 0.000) decision maker are the same as the mean returns. Since NT wheat generated greater average net returns than any of the alternatives, it would be preferred by risk-neutral producers.

Constant absolute risk aversion coefficients greater than zero indicate preference for risk aversion, with 0.002 indicating slight risk aversion and 0.010 indicating more strong aversion to risk. For decision makers with absolute risk aversion coefficients between 0.002 and 0.010, TL wheat is the preferred strategy. Even though the expected annual returns are \$18 ha^{-1} more for NT wheat, for a risk-averse producer, TL wheat is preferred to NT wheat because the standard deviation in net returns is 70% greater for NT wheat. In two of the five years, net returns were less for NT wheat, and in one year, net returns from NT were -\$206 ha^{-1}, \$152 ha^{-1} less than from TL wheat. These results follow from the assumption that the environmental conditions that prevailed over the five years for which data are available for each crop are representative of future environmental conditions. The assumption is that each of the five years is equally likely, and that the five years are sufficient to represent the distributions of net returns.

Risk premiums relative to TL wheat are also reported in Table I-9. These amounts are the difference between the certainty equivalents for TL wheat for a given level of constant absolute risk aversion and the alternative. For all situations other than for a risk-neutral (ARAC = 0.000) decision maker for NT wheat, the risk premiums are negative, which indicates a preference for TL wheat.

Discussion

This study was conducted to determine the expected yield and expected net returns of cotton, wheat, and grain sorghum, for both NT and TL management, for the Southwest Oklahoma District, and to determine the most risk-efficient system. Based on results of the study, wheat was the most economical crop. This finding supports the current cropping decisions made by District producers. From 1997-2007, wheat was seeded on an average of 86% of the dryland area cropped in the District. Mean NT and TL wheat yields were not significantly different; however, NT wheat yields were more variable. The expected economic benefits for switching from TL wheat to NT wheat are not substantial. For risk-neutral producers who farm 1036 ha or more, NT may be preferred. As a result of the increased yield variability, risk-averse producers may prefer TL wheat.

Previous research of the economics of tillage systems has found that farm size matters with less economic incentive for smaller farms, and that the key decision is made when the existing planter, drill, or seeder is replaced (Decker et al., 2009). Switching from TL wheat to NT wheat depends on the availability of a NT grain drill or NT air seeder. A practical time for TL wheat producers in the District to consider switching from TL wheat to NT wheat would be when they replace their existing grain drill or air seeder.

The relative lag in the use of NT in the District can be explained in part by the predominance of continuous wheat production and by the investment required to switch from a conventional drill to a NT drill relative to switching from a conventional planter to a NT planter. No-till systems are relatively more economical for crops seeded with a row planter than for crops seeded with grain drills. The cost difference between NT and conventional row crop planters is relatively less than the cost difference between NT and conventional grain drills and air seeders. The list price for the budgeted 12 m NT row crop planter is nine percent more than the list price for the budgeted 12 m conventional row crop planter. However, the budgeted 11 m NT seeder costs 11 percent more than the budgeted 13 m conventional air seeder.

Grain sorghum NT yields were greater than TL sorghum yields. The yield advantage for NT grain sorghum, combined with the differences in production costs, indicate a clear economic advantage for NT grain sorghum over TL grain sorghum. However, the average net return advantage for NT wheat was \$92 ha^{-1} over NT grain sorghum. Cotton yields were not different across tillage system. Cotton NT was more economical than TL cotton as a result of lower production costs. However, NT wheat had an average net return advantage over NT cotton of \$136 ha^{-1}.

The study did not consider potential differences in the external consequences between TL and NT such as differences in soil loss, changes in water quality of local streams, and long term productivity. Long term consequences of NT in continuous monoculture systems are not fully known. Epplin and Al-Sakkaf (1995) reported yields from a continuous wheat tillage study conducted for ten years at an experiment station in Oklahoma. Relative yields from the NT plots did not improve over time. For the first five years of the study the NT plots yielded an average of 83 percent of the plots that were tilled with a moldboard plow. For the second five years, the NT plots produced only 58 percent as much as the plots that were plowed. Toliver et al. (2011) included a time variable in their meta analysis of 442 tillage experiments conducted at 92 locations across the U.S. Inconsistent with their expectations, they found that yields from NT plots decreased over time relative to yields from tilled plots except for cotton. Neither of these studies addressed differences in soil loss and changes in water quality over time. Additional research would be required to determine differences in external consequences.

Another limitation of the study is that crop rotations were not considered.[2] Crop rotation is rare in the District; however future research is encouraged to consider crop rotations. Given the cost and the length of time required to conduct crop rotation studies in which each year of each rotation is included in every year of the study, researchers are cautioned to select carefully both the crops to include and the sequence.

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[2] A description of several crop rotations that were evaluated, including findings and limitations, is included in the Appendix.

References

American Agricultural Economics Association. 2000. Commodity costs and returns estimation handbook. AAEA, Ames, IA.

Archer, D.W. and D.C. Reicosky. 2009. Economic Performance of Alternative Tillage Systems in the Northern Corn Belt. Agron. J. 101:296-304.

Babcock, B.A., E.K. Choi, and E. Feinerman. 1993. Risk and probability premiums for CARA utility functions. J. Agric. Res. Econ. 18:17–24.

Baumhardt, R.L., R.E. Zartman, and P.W. Unger. 1985. Grain sorghum response to tillage method used during fallow and to limited irrigation. Agron. J. 77:643-646.

Biermacher, J., F.M. Epplin, and K.R. Keim. 2006. Wheat and soybean cropping systems for the Southern Great Plains of the United States as influenced by federal policy. Renewable Agriculture and Food Systems 21:77-83.

Bordovsky, D.G., M. Choudhary, and C.J. Gerard. 1998. Tillage effects on grain sorghum and wheat yields in the Texas Rolling Plains. Agron. J. 90:638-643.

Bordovsky, J.P., W.M. Lyle, and J.W. Keeling. 1994. Crop rotation and tillage effects on soil water and cotton yield. Agron. J. 86:1-6.

Clark, L.E., T.R. Moore, and J.L. Barnett. 1996. Response of cotton to cropping and tillage systems in the Texas Rolling Plains. J. Prod. Agric. 9:55-60.

CTIC, Conservation Technology Information Center. 2004. “National Survey of Conservation Tillage Practices.” Available at http://www.conservationinformation.org/. Accessed on August 3, 2010.

CTIC, Conservation Technology Information Center. 2006. "2006 Crop Residue Management Survey." Available at http://www.ctic.purdue.edu/media/pdf/2006%20CRM%20 summary.pdf Accessed on August 3, 2010.

Daniel, H.A., M.B. Cox, and H.M. Elwell. 1956. "Stubble Mulch and Other Cultural Practices for Moisture Conservation and Wheat Production at the Wheatland Conservation Experiment Station, Cherokee, Okla., 1942–1951." Production Res. Rep. No. 6. USDA-ARS, Washington, DC.

Davidson, J.M., and P.W. Santelmann. 1973. "An Evaluation of Various Tillage Systems for Wheat." Bull. B-711. Oklahoma Agric. Exp. Stn., Stillwater.

Decker, J., F. Epplin, D. Morley, and T. Peeper. 2009. Economics of five wheat production systems with no-till and conventional tillage. Agron. J. 101:364-372.

Doye, D. and R. Sahs. 2009. Oklahoma Farm and Ranch Custom Rates, 2009-2010. Current Rep. CR-205. Oklahoma Coop. Ext. Ser., Stillwater.

Epplin, F.M., T.F. Tice, A.E. Baquet, and S.J. Handke. 1982. Impacts of Reduced Tillage on Operating Inputs and Machinery Requirements. Am. J. Agr. Econ. 64: 1039-1046.

Epplin, F.M., D.E. Beck, E.G. Krenzer, Jr., and W.F. Heer. 1993. Effects of planting dates and tillage systems on the economics of hard red winter wheat production. J. Prod. Agric. 6:57-62.

Epplin, F.M. and G.A. Al-Sakkaf. 1995. Risk-efficient tillage systems and program participation strategies for land subject to conservation compliance. Rev. Agric. Econ. 17:311-321.

Epplin, F.M., G.A. Al-Sakkaf, and T.F. Peeper. 1994. Impacts of alternative tillage methods for continuous wheat on grain yield and economics: Implications for conservation compliance. J. Soil Water Conserv. 49(4):394-399.

Grandy, A.S., G.P. Robertson, and K.D. Thelen. 2006. Do Productivity and Environmental Trade-offs Justify Periodically Cultivating No-till Cropping Systems? Agron. J. 98:1377–1383.

Hardaker, J.B., J.W. Richardson, G. Lien, and K.D. Schumann. 2004. Stochastic efficiency analysis with risk aversion bounds: a simplified approach. Australian J. Agric. and Res. Econ. 48:253–270.

Hardaker, J.B. and G. Lien. 2010. Stochastic efficiency analysis with risk aversion bounds: a comment. Australian J. Agric. and Res. Econ. 54:379–383.

Harper, H.J. 1960. "A 17-Year Comparison of Four Methods of Tillage for Winter Wheat in a Rotation." Bull. B-535. Oklahoma Agric. Exp. Stn., Stillwater.

Heer, W.F., and E.G. Krenzer. 1989. Soil water availability for spring growth of winter wheat (*Triticum aestivum* L.) as influenced by early growth and tillage. Soil and Tillage Res. 14:185–196.

Jones, O.R., and T.W. Popham. 1997. Cropping and tillage systems for dryland grain production in the Southern High Plains. Agron. J.. 89:222-232.

Key, N., and M.J. Roberts. 2007. Commodity Payments, Farm Business Survival, and Farm Size Growth. U.S. Department of Agriculture, Economic Research Service, ERR-51.

Kletke, D., and R. Sestak. 1991. The operation and use of MACHSEL: A farm machinery selection template. Department of Agricultural Economics Computer Software Series CSS-53. Oklahoma State University., Stillwater, OK.

Littell, R.C., G.A. Milliken, W.W. Stroup, and R.D. Wolfinger. 1996. SAS system for mixed models. SAS Inst., Cary, NC.

Meyer, J., J.W. Richardson, and K.D. Schumann. 2009. Stochastic efficiency analysis with risk aversion bounds: a correction. Australian J. Agric. and Res. Econ. 53:521–525.

Natural Resource Conservation Service. 2010. “Web Soil Survey.” Available at http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm. Accessed on June 21, 2010.

Oklahoma Mesonet. 2010. “Daily Data Retrieval.” Available at http://mesonet.org/. Accessed on July 26, 2010.

Piepho, H.P., A. Büchse, and K. Emrich. 2003. A hitchhiker’s guide to mixed models for randomized experiments. J. Agron. Crop Sci. 189:310–322.

Reinschmiedt, L.L. 1973. “Study of the Relationship Between Rainfall and Fieldwork Time Available and its Effect on Optimal Machinery Selection. MS Thesis, Oklahoma State University.

Richardson, J.W., K. Schumann, and P. Feldman. 2001. “Simulation for Excel to Analyze Risk.” Dept. Ag. Econ. Texas A&M University, College Station.

Segarra, E., J.W. Keeling, and J.R. Abernathy. 1991. Tillage and cropping systems effects on cotton yield and profitability on the Texas Southern High Plains. J. Prod. Agric. 4:566-571.

Toliver, D.K., J.A. Larson, B.C. English, R.K. Roberts, D.G. de la Torre Ugarte, and T.O. West. 2011. "Effects of no-tillage production practices on crop yields as influenced by crop and growing environment factors." Paper presented at the Southern Agricultural Economics Association Annual Meeting, February 5-8, 2011, Corpus Christi, TX.

USDA-NASS. 2009. "Oklahoma Agricultural Statistics 2009." Oklahoma Agricultural Statistics, Oklahoma City, OK.

USDA-NASS. 2010. "Oklahoma Quick Stats (Crops)." Available at http://www.nass.usda.gov/QuickStats/PullData_US_CNTY.jsp. Accessed on June 23, 2010.

U.S. Department of Commerce. 2011. Oklahoma District 7 Palmer Drought Severity Index. National Oceanic and Atmospheric Administration. National Climatic Data Center.

Williams, J.R., T.W. Roth, and M.M. Claassen. 2000. Profitability of alternative production and tillage strategies for dryland wheat and grain sorghum in the Central Great Plains. J. Soil Water Conserv. 55:49-56.

Williams, J.R., R.V. Llewelyn, D.L. Pendell, A. Schlegel, and T. Dumler. 2010. A risk analysis of converting Conservation Reserve Program acres to a wheat–sorghum–fallow rotation. Agron. J. 102:612-622.

Zingg, A.W., and C.J. Whitfield. 1957. "A Summary of Research Experience with Stubble-Mulch Farming in the Western States. USDA Tech. Bull. 1166. USDA, Washington, DC.

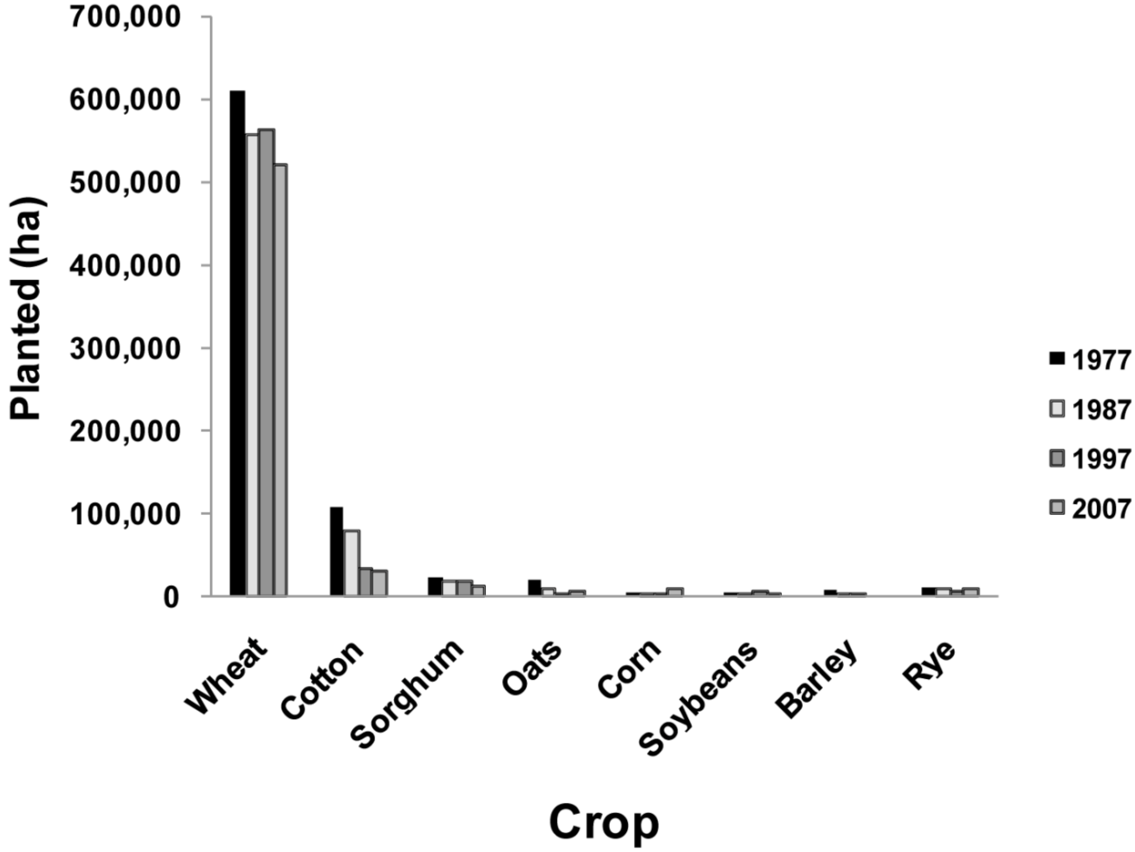

Fig. I-1. Land planted to dryland crops in the Southwest Oklahoma Agricultural Statistics District in 1977, 1987, 1997, and 2007 (ha).

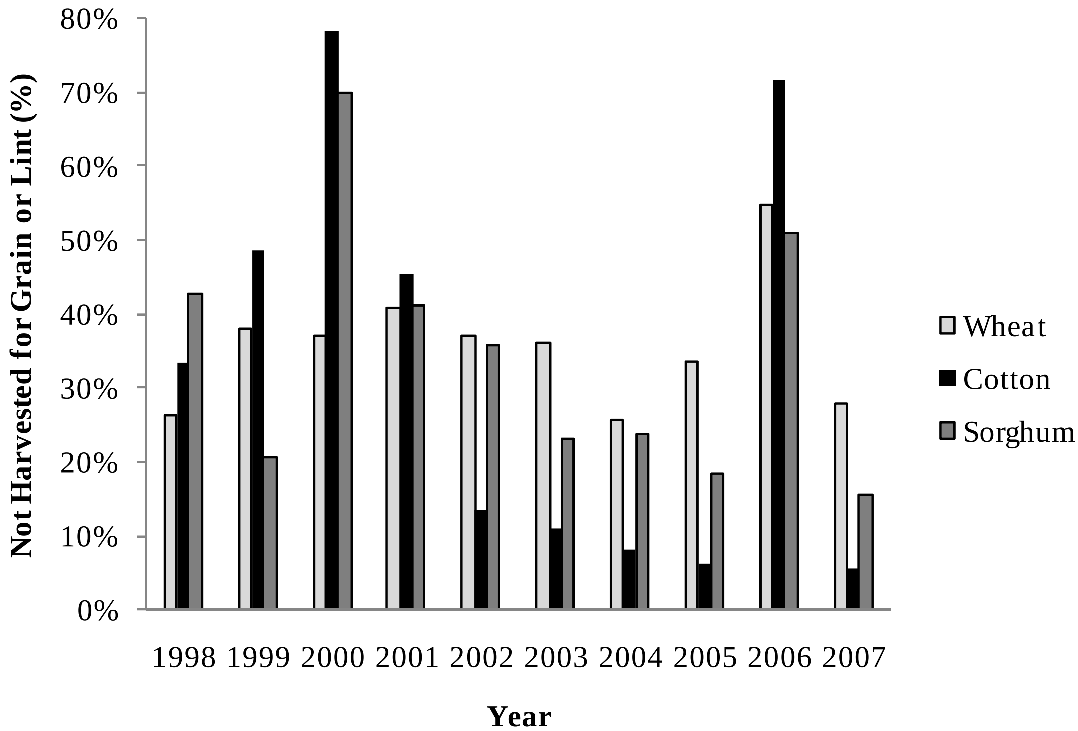

Fig. I-2. Proportion of area planted to wheat, cotton, and sorghum in the Southwest Oklahoma Agricultural Statistics District not harvested, 1998-2007.

Table I-1. Field operations for cotton, wheat, and grain sorghum

		Systems					
		Tilled			No-till		
Field operations	Month	Cotton	Wheat	Sorghum	Cotton	Wheat	Sorghum
Chisel	March	x		x			
Disk	March	x		x			
Apply herbicide (glyphosate)	March				x		
Apply herbicide (glyphosate and s-metolachlor)	March						x
Chisel and apply fertilizer (82-0-0)	April			x			
Apply fertilizer (82-0-0) with no-till NH_3 applicator	April						x
Plant grain sorghum	April			x			
Plant grain sorghum with no-till planter	April						x
Apply herbicide (atrazine) 1/6th of the time	April			x			x
Apply herbicide (basagran) 1/6th of the time	May			x			
Apply fertilizer (82-0-0) chisel	May	x					
Apply herbicide (trifluralin)	May	x					
Cultivate	May	x					
Apply fertilizer (82-0-0) with no-till NH_3 applicator	May				x		
Plant cotton	May	x					
Plant cotton with no-till planter	May				x		
Apply herbicide (glyphosate)	May				x		
Harvest wheat grain	May		x			x	
Chisel	June		x				
Disk	June		x				
Apply herbicide (glyphosate and s-metolachlor)	June	x					
Apply herbicide (glyphosate)	June					x	
Apply herbicide (glyphosate)	June				x		
Disk	July		x				
Apply herbicide (glyphosate)	July					x	
Chisel and apply fertilizer (82-0-0)	August		x				
Apply fertilizer (82-0-0) with no-till NH_3 applicator	August					x	
Harvest grain sorghum	September			x			x
Apply herbicide (paraquat) 1/6th of the time	September						x
Plant wheat	October		x				
Plant wheat with no-till drill	October					x	
Apply defoliant (thidiazuronr-diuron)	October	x			x		
Harvest cotton	October	x			x		
Apply herbicide (sulfosulfuron) 1/6th of the time	November		x			x	
Rotary mow	November	x		x	x		x

Table I-2. Machinery complements for a 1036 ha cotton farm

Machine	List price ($)	Machine width (m)	Tilled	No-till
71 kW tractor	$73,000		x	x
Sprayer	$34,000	27	x	x
Rotary mower	$23,000	6	x	
No-till NH_3 applicator	$37,967	9		x
101 kW tractor	$101,000			x
No-till planter	$83,000	12		x
Rotary mower	$23,000	6		x
116 kW tractor	$119,000		x	
Planter	$76,000	12	x	
Tandem disk	$29,000	6	x	
242 kW tractor	$200,000		x	
Chisel	$41,000	11	x	
NH_3 setup for chisel	$4,050		x	
Cultivator	$64,000	18	x	
Machinery labor (hrs ha^{-1})			1.398	0.736
Average machinery investment ($ ha^{-1})			$387.79	$192.35

Table I-3. Machinery complements for a 1036 ha wheat farm

Machine	List price ($)	Machine width (m)	Tilled	No-till
71 kW tractor	$73,000			x
Sprayer	$34,000	27		x
116 kW tractor	$119,000		x	
Tandem Disk	$29,000	6	x	
Sprayer	$34,000	27	x	
160 kW tractor	$151,000			x
No-till NH_3 applicator	$46,783	12		x
No-till air seeder	$141,348	11		x
242 kW tractor	$200,000		x	
Chisel	$41,000	11	x	
NH_3 setup for chisel	$4,050		x	
Air seeder	$126,987	13	x	
Machinery labor (hrs ha^{-1})			1.087	0.499
Average machinery investment ($ ha^{-1})			$351.98	$246.07

Table I-4. Machinery complements for a 1036 ha grain sorghum farm

Machine	List price ($)	Machine width (m)	Tilled	No-till
71 kW tractor	$73,000		x	x
No-Till NH_3 Toolbar	$37,967	9		x
Sprayer	$34,000	27	x	x
Rotary Mower	$23,000	6	x	
101 kW tractor	$101,000			x
No-Till Planter	$83,000	12		x
Rotary Mower	$23,000	6		x
242 kW tractor	$200,000		x	
Chisel	$41,000	11	x	
NH_3 Setup For Cultivator	$4,050		x	
Cultivator	$64,000	18	x	
Tandem Disk	$43,000	9	x	
Planter	$76,000	12	x	
Machinery labor (hrs ha^{-1})			0.951	0.674
Average machinery investment ($ ha^{-1})			$331.29	$190.19

Table I-5. Monthly rainfall totals at the site near Altus, OK (mm) and annual PDSI (Palmer drought severity index) values for the Southwest Oklahoma District

Month	2003	2004	2005	2006	2007	2008	Mean	Standard deviation	Mean (1971-2008)
January	0	101	51	1	34	0	31	37	26
February	18	50	29	1	5	26	22	16	29
March	15	71	4	21	70	48	38	26	44
April	64	57	27	53	34	62	50	14	60
May	19	1	109	74	69	63	56	36	111
June	184	240	50	3	136	85	116	80	111
July	2	89	61	21	35	46	42	28	49
August	118	59	83	39	82	92	79	25	74
September	12	19	91	81	7	20	38	34	79
October	9	18	76	122	32	93	59	42	67
November	30	178	0	16	2	1	38	63	35
December	1	7	3	62	46	1	20	25	29
Year Total	473	888	584	494	553	537	588	139	714
PDSI[†]	-0.17	0.32	4.14	-2.17	1.40	-0.81			

[†] Annual PDSI (Palmer drought severity index) values for the Southwest Oklahoma District. A PDSI value of 0 is regarded as normal. Values of -2, -3, and -4 indicate moderate, severe, and extreme drought, respectively. Similarly values of +2, +3, and +4 reflect moderate, severe and extreme wetness (U.S. Department of Commerce, 2011).

Table I-6. Mean yield of cotton, wheat, and grain sorghum for tilled and no-till production systems by year in Southwest Oklahoma on a Hollister silty clay loam soil (kg ha^{-1} yr^{-1})

	2003	2004	2005	2006	2007	2008	Mean	Standard Deviation	F Value	P-Value
Cotton Lint										
Tilled	278	402	760	0	820	230	415	114		
No-Till	316	304	691	0	829	308	408	85	0.06	0.81
Cotton Seed										
Tilled	474	671	1347	0	1323	312	688	188		
No-Till	556	500	1270	0	1309	445	680	132	0.03	0.87
Wheat Grain										
Tilled	N/A	3803	3729	1431	3319	3138	3080	291		
No-Till	N/A	4576	3433	0	3299	3527	2964	401	0.36	0.55
Grain Sorghum										
Tilled	†	2942	5406	0	2705	1932	2597	557		
No-Till	†	3310	5559	3208	4974	1029	3616	764	7.26	0.01

† The 2003 grain sorghum crop was destroyed by birds. Grain sorghum mean yields do not include yields from 2003.

Table I-7. Costs and returns estimates for a 1036 ha farm (\$ ha^{-1}) (2003-2008 prices).

	Tilled systems			No-till systems		
	Cotton	Wheat	Sorghum	Cotton	Wheat	Sorghum
Revenue based on overall mean yield:						
Wheat (\$0.17 kg^{-1})		517.44			498.02	
Cotton						
Lint (\$1.10 kg^{-1})	456.65			448.85		
Seed (\$0.13 kg^{-1})	74.03			88.46		
Grain Sorghum (\$0.11 kg^{-1})			281.80			392.29
Total Revenue	530.68	517.44	281.80	537.30	498.02	392.29
Operating Inputs:						
Wheat Seed		38.04			38.04	
Cotton Seed (glyphosate-tolerant)	89.96			89.96		
Grain Sorghum Seed (treated)			9.19			9.19
Fertilizers						
Anhydrous Ammonia	60.27	75.09	60.27	60.27	75.09	60.27
Herbicides						
glyphosate (480 g L^{-1} a.i.)				7.11	14.23	7.11
glyphosate (660 g L^{-1} a.i.)	18.48			36.95		
s-metolachlor	37.49		56.24			24.93
paraquat						6.99
atrazine			2.54			2.54
trifluralin	10.35					
basagran			7.90			
sulfosulfuron		5.83			5.83	
Defoliant						
thidiazuron-diuron	31.54			31.54		
Adjuvants						
nonionic surfactant	8.10	0.32		16.60	1.14	0.47
crop oil concentrate			2.84			1.90
Grain Harvest and Hauling		78.62	80.16		77.05	97.00
Cotton Harvest	91.51			89.95		
Cotton Ginning	61.26			61.80		
Machinery Fuel, Lube, and Repair	42.01	47.72	37.99	16.33	25.94	15.36
Total Operating Costs	450.97	245.62	257.13	410.51	237.30	225.77
Fixed Costs:						
Interest (8.00%)	31.02	28.16	26.50	15.39	19.69	15.22
Taxes (1.00%)	6.40	5.34	5.38	3.38	4.30	3.38
Insurance (0.60%)	2.32	2.10	1.98	1.16	1.48	1.14
Depreciation	49.28	39.37	37.64	28.33	26.92	24.11
Total Fixed Costs	89.02	74.96	71.51	48.26	52.39	43.84
Total Costs	539.99	320.58	328.64	458.77	289.69	269.61
Net Returns	-9.31	196.85	-46.84	78.53	208.33	122.67

Table I-8. Net returns to land, labor, overhead, risk, and management from cotton, wheat, and grain sorghum for tilled and no-till production systems by year for a 1036 ha farm ($ ha^{-1}).

	2003	2004	2005	2006	2007	2008	Mean†
Cotton							
Tilled	-133	-12	345	-356	299	-187	-7
No-Till	-15	-31	360	-275	479	-31	81
Wheat							
Tilled	N/A	319	278	-54	236	215	199
No-Till	N/A	463	256	-206	266	307	217
Grain Sorghum							
Tilled	N/A	-2	225	-235	-77	-122	-42
No-Till	N/A	81	288	122	242	-109	125

† Mean net returns in Table I-8 differ from mean net returns in Table I-7 due to rounding error in yields and harvesting cost. For the budgets in Table I-7, the mean yield across years was used to calculate the grain harvest and hauling, cotton harvest, and cotton ginning costs. Each of these costs is a function of yield. In Table I-8 the year specific yield was used to calculate the grain harvest and hauling, cotton harvest, and cotton ginning costs.

Table I-9. Net returns certainty equivalents and tilled wheat risk premiums by cropping system for various absolute risk aversion coefficients.

	Absolute Risk Aversion Coefficients (ARAC)					
Cropping system	0.000	0.002	0.004	0.006	0.008	0.010
Wheat	Certainty equivalents ($ ha^{-1})					
Tilled	199	180	158	134	111	90
No-Till	217	160	94	34	-13	-48
Cotton						
Tilled	18†	-54	-113	-158	-191	-215
No-Till	100†	28	-31	-74	-106	-130
Grain Sorghum						
Tilled	-42	-64	-83	-99	-112	-123
No-Till	125	105	84	63	43	26
	Risk Premium Relative to Tilled Wheat ($ ha^{-1})					
Wheat						
No-Till	18‡	-20§	-64	-100	-124	-138
Cotton						
Tilled	-181	-233	-271	-292	-302	-305
No-Till	-98	-152	-188	-208	-217	-220
Grain Sorghum						
Tilled	-241	-244	-240	-233	-223	-213
No-Till	-74	-75	-74	-71	-68	-64

† Cotton observations for 2003 are not included in the risk analysis.

‡ This positive value indicates the dollar per ha benefit of no-till wheat over tilled wheat for risk-neutral producers.

§ This negative value indicates the dollar per ha benefit of tilled wheat over no-till wheat for slightly risk-averse producers.

PAPER II

Lease Rate for Fall-Winter Wheat Pasture Required to Compensate for the Reduced Wheat Grain Yield and Additional Cost of Dual-Purpose Wheat [3]

Abstract

Winter wheat can be managed to produce a substantial quantity of high quality fall-winter forage. Wheat producers may lease the grazing rights to livestock producers. This system can be used to generate income from both forage and grain, but results in a lower expected grain yield than wheat managed to produce only grain. The lease rate in terms of cents per pound of livestock weight gain required to offset the additional costs and lower grain yield depends on the market price of wheat. This study was conducted to determine the minimum lease rate for fall-winter grazing necessary for dual-purpose wheat to breakeven with grain-only wheat. Breakeven wheat pasture rental rates were determined to be $0.30, $0.44, $0.59 per pound of gain for wheat prices of $3, $5, and $7 per bushel, respectively.

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[3] This paper has been prepared using the style required for the *Journal of the American Society of Farm Managers and Rural Appraisers*. The assistance of Dr. Jeffrey Edwards who conducted the variety trial experiments, and Dr. Gerald Horn who conducted the beef gain experiments, is gratefully acknowledged.

Introduction

Winter wheat may be managed in the Southern Plains to produce high quality forage that can be grazed by livestock, typically from mid-November through February. If livestock are removed from the wheat prior to the first hollow stem stage of development (emergence from winter dormancy), the wheat will mature and produce wheat grain. True et al. found that in 1996 two-thirds of Oklahoma's wheat acres were planted with the intention of being used to produce both fall-winter forage and grain. Wheat producers often lease the rights to graze the fall-winter forage to livestock producers (True et al., 2001; Hossain et al., 2004). Typically wheat pastures are stocked with light weight (450 to 550 pound) steers or heifers that have an opportunity to gain 200 to 300 pounds during the season. The most typical lease arrangement is for the livestock owner to pay the wheat producer a fixed rate per pound of weight gained by the grazing livestock. The wheat producer accepts the weight gain risk and the livestock owner accepts the livestock price risk.

Dual-purpose wheat is planted early to establish a forage base before winter so that livestock have sufficient forage throughout the fall-winter grazing season. Previous small plot studies have found that expected grain yield is less for early planted wheat (dual-purpose) than for wheat (grain-only) planted later to maximize grain yield due to planting date effects (Duke et al.; Edwards et al., 2011; Hossain, Epplin, and Krenzer, 2003; Epplin, Krenzer, and Horn, 2001; Lyon, Baltensperger, and Siles, 2001; and Epplin, Hossain, and Krenzer, 2000). Typically producers plant dual-purpose wheat in mid September (Hossain et al., 2004; Krenzer, 2000; True et al., 2001); whereas, grain-only wheat is planted in October (Heer and Krenzer; Krenzer, 2000; Lyon et al., 2007).

On average wheat planted in early September yields substantially more fall-winter forage but less grain than wheat planted in October.

Dual-purpose wheat requires more seed and more nitrogen. The optimal seeding rate for dual-purpose wheat is 1.5 to 2 times greater than the optimal seeding rate of grain-only wheat (Edwards et al., 2011; Epplin, Krenzer, and Horn, 2001; Hossain, Epplin, and Krenzer, 2003; and Krenzer, 1991). Early sowing, increased plant population density, and the additional nitrogen increase the level of expected fall vegetative growth available for grazing livestock (Edwards et al., 2011; Krenzer, 1991; Edwards, 2009).

Historical estimates of wheat pasture rental rates obtained in biennial surveys conducted by Doye and Sahs (1991 - 2010) are reported in Table II-1. From 1991 to 2006 the average wheat pasture rental rate ranged from \$0.31 to \$0.44 per pound of gain. As a result of the reduction in grain yield, the wheat pasture lease rate required for dual-purpose wheat to breakeven with grain-only wheat depends in part on the price of wheat grain. Wheat grain prices increased in 2007 and 2008 and wheat pasture rental rates rose in 2008 to an average of \$0.44 per pound of gain. Wheat prices declined in 2009 and 2010 and average rental rates declined to \$0.39 per pound of gain in 2010.

Increased variability in the price of wheat grain has increased the value of knowing the wheat pasture lease rate required for dual-purpose wheat to break even with grain-only wheat. The expected sale price of wheat grain at harvest has become relatively less certain (Table II-1). This uncertainty has made it more difficult to compute with certainty a pre-season estimate of the expected value of the grain yield forgone when wheat is managed to produce both fall-winter forage and grain rather than just grain. An estimate of the value of the grain yield forgone is necessary to determine the opportunity cost of managing wheat for both pasture and grain versus managing for only grain. The objective of this study is to determine the minimum lease rate for fall-winter grazing necessary for dual-purpose wheat to breakeven with grain-only wheat for three sets of wheat grain prices. This information will be useful for winter wheat producers who must decide whether to plant wheat with the intention of producing both fall-winter forage and grain or to plant with the intention of producing only grain. The information will also be of value to livestock producers who lease wheat pasture from wheat producers.

Methods

Grain Yield

The SAS mixed model procedure (PROC MIXED) can be used to determine if grain yields are different between grain-only and dual-purpose wheat systems (Littell et al.; Piepho, Büchse, and Emrich). The mixed model procedure will be used as it allows for repeated measures on the same test plot across several years and also because it accounts for the year effects (year to year variability) as random (Littell et al.).

Budgets

Enterprise budgets will be estimated using inputs and practices common to the region. Two base budgets will be estimated, one for grain-only wheat and the other for dual-purpose wheat. Three wheat grain prices of $3, $5, and $7 per bushel will be considered. The $3 per bushel grain price roughly reflects the average marketing year price of wheat from 1986 to 2005. The $5 per bushel grain price roughly reflects the 2006 to 2010 five year average marking price of wheat, which is $5.57 per bushel. The $7 per bushel grain price reflects a hedged wheat price that has been possible to lock in for every year since 2007, except for 2009. Gross returns for grain-only wheat will be calculated by multiplying the grain-only average yield by wheat prices of \$3, \$5, and \$7 per bushel. Gross returns for the dual-purpose system will be calculated by multiplying the dual-purpose average wheat yield by wheat prices of \$3, \$5, and \$7 per bushel, multiplying the average steer gain per acre by the breakeven rate for wheat pasture rental, and summing the two products. The breakeven rental rate will be determined using the following equation:

(1) $$BE_G = ((P_w)(W_{GO} - W_{DP}) + \left[\left(1 + r\left(\frac{m}{12}\right)\right) * \left(P_n(N_{DP} - N_{GO}) + P_s(S_{DP} - S_{GO})\right)\right] - (H) * ((1 - \lambda) * \left((W_{GO} - 20)) - ((1 - \omega) * (W_{DP} - 20)\right)\right) - (HL)(W_{GO} - W_{DP}))/G$$

where BE_G is the breakeven wheat pasture rental rate in \$ per lb. of gain,

P_W is the price of wheat grain in \$ per bushel,

W_{GO} is the grain only wheat grain yield in bushels per acre,

W_{DP} is the dual purpose wheat grain yield in bushels per acre,

r is the interest rate,

m is the number of months between planting (investment in seed and nitrogen) and harvest,

P_n is the price of anhydrous ammonia in \$ per pound,

N_{DP} is the anhydrous ammonia rate required for dual-purpose production in pounds per acre,

N_{GO} is the anhydrous ammonia rate required for grain-only production in pounds per acre,

P_s is the price of seed wheat in \$ per bushel,

S_{DP} is the seeding rate required for dual purpose production in bushels per acre,

S_{GO} is the seeding rate required for grain only production in bushels per acre,

H is the additional harvesting cost above 20 bushels per acre in $ per bushel,

λ is equal to 1 if $W_{GO} < 20$,

ω is equal to 1 if $W_{DP} < 20$,

HL is the hauling cost in $ per bushel, and

G is beef weight gain in pounds per acre.

Equation (1) can be solved to determine the lease price per pound of steer weight gain at which the net returns from the dual-purpose system equal the net returns from the grain-only system. The breakeven lease price of gain (BE_G) is the rental rate at which a risk-neutral wheat producer would be indifferent between growing wheat for grain-only and growing wheat for dual-purpose and leasing the forage. However, the market would have to provide a greater wheat pasture lease rate to entice producers to grow dual-purpose wheat and lease the grazing rights.

Total cash costs will be estimated by summing the cost of inputs and services. The price of seed wheat is assumed to be correlated with the price of wheat grain. To test this assumption, seed wheat prices and prices received for wheat grain were retrieved from the National Agricultural Statistics Service from 2002 through 2010 and the SAS correlation procedure (PROC CORR) was used to determine if correlation existed between prices of seed wheat and grain prices. The correlation coefficient was 0.71 and the p-value was 0.03, which indicates statistically significant correlation. Since the price of seed wheat is correlated with the price of wheat grain a ratio of the seed wheat price and the grain price can be used to determine the price of seed wheat at varying levels of wheat grain prices. The price of seed wheat and wheat grain were retrieved from NASS for the time period of 2002-2010. Ratios were calculated for each year and then averaged across years to return the average ratio. Using this method the price of seed wheat is 2.41 times greater than the price of wheat grain, thus the price of seed in the budget can be set equal to 2.41 times the market price of wheat and in equation (1) P_S is set equal to 2.41*P_W. Fertilizer and herbicide prices were obtained from dealers and distributors in the region. Fertilizer application, herbicide application, and custom harvesting costs were obtained from a survey conducted by Doye and Sahs (2009).

Three common assumed differences in total costs between the two wheat systems are based on the seeding rate, the amount of nitrogen applied, and the harvesting expense. Grain-only wheat has a budgeted seeding rate of 60 pounds per acre, while the dual-purpose wheat has a budgeted seeding rate of 120 pounds per acre. All nitrogen is assumed to be applied pre-plant using anhydrous ammonia and diammonium phosphate in both wheat systems. Grain-only is budgeted to receive 82 pounds of nitrogen per acre, while the dual-purpose wheat is budgeted to receive 115 pounds of nitrogen per acre. Harvesting and hauling expenses also differ between the two wheat systems because harvesting cost is a discontinuous function of yield. For example, the hauling cost as represented by HL in equation (1) differs between wheat systems because the hauling cost is a function of the number of bushels hauled [($HL*W_{GO}$) and ($HL*W_{DP}$)]. Since the expected yield of dual-purpose wheat is less than the expected yield of grain-only wheat the harvesting and hauling cost is expected to be less for the dual-purpose system.

Risk Analysis

Wheat yields and livestock weight gain are stochastic variables affected by weather and management effects. However, the empirical yield and gain distributions can be used to estimate a distribution of net returns for both wheat systems using the breakeven rental rate as a proxy for the price of gain assuming that prices and input levels are fixed and assuming that dual-purpose wheat yield and gain are independent.

Stochastic efficiency with respect to a function (SERF) can be used to compare the distributions of net returns. SERF can also be used to estimate a risk premium relative to grain-only wheat for several absolute risk aversion coefficients. These risk premiums can be divided by expected steer gain and multiplied by negative one to show the additional lease rate required by producers with varying levels of risk aversion to be indifferent between grain-only and dual-purpose wheat. The key assumptions necessary for SERF are that the empirical data must represent the entire distribution and that each year represented is equally likely to occur. SERF ranks the two production systems in terms of certainty equivalents (CE) for a given level of risk aversion enabling determination of the risk premiums (Hardaker et al., 2004; Meyer, Richardson, and Schumann, 2009; Archer and Reicosky, 2009; Hardaker and Lien, 2010; Williams et al., 2010). The difference between CE for any two production systems represents the risk premium, which is a monetary estimate of the minimum amount a producer would have to be paid to switch from a production system that has a greater CE to the production system with a lower CE. The spreadsheet add-in SIMETAR can be used to calculate certainty equivalents and risk premiums using SERF (Richardson, Schumann, and Feldman, 2001).

Data

Grain Yield

Wheat yield data for both dual-purpose and grain-only production systems were obtained from side-by-side experiments conducted at the Oklahoma State University Wheat Pasture Research Unit (WPRU) near Marshall, OK (36° 6' 57.78" N, 97° 35' 42.51" W) from 1999 to 2011. In each year trials consisting of 18-24 varieties were tested (Edwards et al., 2011). The dual-purpose plots were planted between August 31 and September 25. The grain-only plots were planted in October. The two production systems were adjacent, but were separated by an electric fence so that the grain-only plots were not grazed. Grazing was initiated on the dual-purpose plots 45 to 60 days after planting. Grazing on dual-purpose plots was terminated at the first hollow stem stage of growth for the earliest variety, usually near March 1. This study will use the wheat yields from the varieties trial experiment in an economic analysis of grain-only and dual-purpose wheat.

Steer Gain

Steer weight gain data were also obtained from the WPRU from 1990 to 2000. Steers were grazed on dual-purpose wheat managed the same way as the dual-purpose wheat in the variety trial experiments. Grazing was initiated after the wheat had become well anchored into the soil and steers were removed from the wheat at the development of first hollow stem. During the grazing period the steers did not receive any supplemental feed other than hay during periods when snow covered the wheat field. Steers were weighed prior to grazing wheat and were weighed again after grazing was terminated to determine steer weight gain (Kaitibie et al., 2003).

Duke et al. (2011) found that experienced Oklahoma wheat producers who produce dual-purpose wheat regard average daily gain and wheat grain yield to be uncorrelated. Weather events that affect forage yields occur in the fall and weather events that affect grain yields largely occur in the early spring after the cattle have been removed from the wheat. Kaitibie et al. (2003) reported seven years where wheat grain yields and steer gain are available for the same time period. To determine if wheat grain yields are correlated with steer gain the correlation procedure in SAS (PROC CORR) was used. Grain yields and steer gain had a correlation coefficient of 0.60 and a p-value of 0.12, such that the null hypothesis equals zero correlation could not be rejected. Since no significant correlation was found between grain yields and steer gain this study will randomly draw from the empirical distribution of steer gains and pair them with a dual-purpose grain yield for economic analysis.

Risk Analysis

Net returns distributions were estimated from the 13 years of observations for grain-only and dual-purpose wheat yields and the 11 years of observations of beef gain per acre using stochastic efficiency with respect to a function (SERF). Since two different time periods of data are being, 1248 randomly drawn observations of steer gain are paired with randomly drawn dual-purpose wheat yields. One thousand two hundred forty-eight observations were chosen as this was the number of yield observations available for the grain-only and dual-purpose system. For years when less than 24 wheat varieties were tested, the mean wheat yield for that year and wheat system was added to the list of empirical data so that 96 total observations were available for each year.

Results

Grain Yield

Mean yields by year and production system are reported in Table II-2. Wheat yields were statistically different between wheat systems. Grain-only wheat yielded on average 40 bushels per acre, which was greater ($P \leq 0.05$) than the dual-purpose average yield of 33 bushels per acre. This finding is consistent with results reported by Duke et al. (2011); Edwards et al. (2011); Hossain, Epplin, and Krenzer (2003); Epplin, Krenzer, and Horn (2001); Lyon, Baltensperger, and Siles (2001); and Epplin, Hossain, and Krenzer (2000). However, in three of thirteen years dual-purpose wheat generated greater wheat yields than grain-only wheat.

Steer Gain

Mean steer gains per acre are reported by year in Table II-3. Gain per acre ranged from a low of 0 pounds per acre in 1996 to a high of 199 pounds per acre in 1994. During the 1996 growing season insufficient wheat pasture was produced on the dual-purpose plots due to drought to permit grazing and zero gain was recorded. The mean steer gain during the grazing season from 1990 to 2000 was 134 pounds per acre.

Budgets

Base budgets are reported in Tables II-4, II-5, and II-6 for wheat grain prices of $3, $5, and $7 per bushel respectively. Breakeven pasture rental rates were computed and used in the enterprise budgets so grain-only wheat and dual-purpose wheat have the same expected net return of -$53, $22, and $98 per acre for wheat prices of $3, $5, and $7 per bushel, respectively. Since the price of seed wheat is a function of the grain price, grain-only and dual-purpose seed costs differ among the three base budgets. At an expected grain price of $3 per bushel, dual-purpose wheat is expected to require an additional $20 per acre in total cost. For grain prices of $5 and $7 per bushel, dual-purpose is expected to require an additional $25 and $30 per acre respectively. Dual-purpose wheat has greater total costs as a result of higher seeding rate and a higher rate of nitrogen fertilizer. Because expected harvest costs are a function of grain yield, they are slightly lower for dual-purpose wheat. For dual-purpose wheat to breakeven with grain-only wheat, the wheat pasture rental rate must adjust according to the wheat price when cost and production differences are held constant.

Table II-7 includes the rental rates required for dual-purpose wheat to breakeven with grain-only wheat for the mean levels of livestock weight gain and mean levels of both dual-purpose and grain-only wheat yields. When the price of wheat grain is $3 per bushel, a $0.30 per pound of gain pasture rental rate is required for dual-purpose wheat to breakeven with grain-only wheat. The breakeven rental rates increase up to $0.44 and $0.59 per pound of gain when the wheat price increases to $5 and $7 per bushel, respectively. Since the cost difference between dual-purpose and grain-only wheat is sensitive to the price of anhydrous ammonia, the price of anhydrous ammonia was both increased and reduced by 50 percent to determine how sensitive the breakeven rental rates are to the price of nitrogen fertilizer. The 50 percent price changes were used for the price of anhydrous ammonia as the mean price of anhydrous ammonia fluctuated by roughly 50 percent during the 1999-2010 period. The breakeven rental rates for each of the three anhydrous ammonia prices and each of the three wheat prices are included in Table II-7. When the price of anhydrous ammonia is reduced by 50 percent, the breakeven pasture rental rates are $0.25, $0.39, and $0.53 per pound of gain for $3, $5, and $7 wheat, respectively. When the price of anhydrous ammonia is increased by 50 percent, the breakeven pasture rental rates are $0.36, $0.50, and $0.65 per pound of gain for $3, $5, and $7 wheat, respectively.

Risk Analysis

Results from the SERF analysis are reported in Tables II-8, II-9, and II-10 for wheat grain prices of $3, $5, and $7 per bushel. Net returns CE are reported for both wheat systems for five constant absolute risk aversion coefficients (ARAC). Since the breakeven pasture rental rate was used in the formulation of the net returns distribution, it is expected that the risk neutral producer (ARAC= 0.000) would be indifferent between grain-only and dual-purpose wheat. The CE are not equal for the risk neutral producer (ARAC= 0.000) due to rounding error in the breakeven pasture rental rate. For each of the three grain prices, dual-purpose wheat has the greater CE at ARAC of 0.000 and grain-only has the greater CE at ARAC of 0.002 and greater. Grain-only wheat is the preferred system for risk-averse producers (ARAC between 0.002 and 0.008) when the value of livestock gain is priced at the breakeven level because variability in net returns is less for the grain-only system than returns from the dual-purpose system. The standard deviation in net returns was 24, 21, and 20 percent greater for dual-purpose wheat when compared to grain-only wheat at grain prices of $3, $5, and $7 per bushel.

Risk premiums are also reported in Tables II-8, II-9, and II-10. Risk premiums in these tables represent the difference in CE between grain-only wheat and dual-purpose wheat. The risk premium is positive for the risk neutral wheat producers (ARAC=0.000) when grain price is $3 per bushel and the value of livestock weight gain is set at the breakeven level, which indicates a preference for dual-purpose wheat. Risk premiums become negative for levels of the ARAC that would be appropriate for risk averse producers (ARAC= 0.002 to 0.008). A risk-averse producer would require a lease rate for the fall-winter wheat pasture in excess of that required to breakeven to prefer dual-purpose to grain-only wheat. For risk-averse producers with ARAC of 0.002 and greater, a lease rate in excess of the breakeven rate would be required to entice production of dual-purpose wheat.

For the mean livestock weight gain level of 134 pounds per acre, risk-averse producers (ARAC=0.004) would require an additional $1 per acre (so the pasture rental rate would have to increase approximately two percent to $0.31 per pound of gain) to be indifferent between grain-only and dual-purpose wheat. For a more strongly risk averse producer (ARAC= 0.008), the stocker cattle would have to generate an additional $2.61 per acre, which would increase the price per pound of gain by approximately six percent to $0.32 per pound of gain.

When the price of wheat grain is $5 and $7 per bushel, risk premiums are negative for producers with ARAC of 0.002 and greater, which indicates that a greater expected return is required to entice risk averse producers to switch from grain-only to dual-purpose wheat. For dual-purpose wheat to be economically competitive with grain-only wheat, the wheat pasture rental rate must be in the range of $0.43 to $0.50 per pound of gain for an expected grain price of $5 per bushel and $0.58 to $0.71 per pound of gain for an expected grain price of $7 per bushel depending on the wheat producer’s level of risk aversion.

Conclusion

This study was conducted to determine the minimum lease rate for fall-winter grazing necessary for dual-purpose wheat to breakeven with grain-only wheat. Breakeven pasture rental rates above cash costs (excluding land, labor, machinery fixed costs, overhead, and management costs) were determined for three levels of wheat grain price. The breakeven pasture rental rate was determined to be $0.30, $0.44, and $0.59 per pound of gain for expected wheat prices of $3, $5, and $7 per bushel. The breakeven pasture rental rate is sensitive to the price of wheat grain and also to the price of nitrogen fertilizer. When anhydrous ammonia costs $0.17 per pound of NH_3 estimated breakeven pasture rental rates were $0.25, $0.39, and $0.53 per pound of gain for grain prices of $3, $5, and $7 per bushel, respectively. When the price of anhydrous ammonia was increased to $0.52 per pound of NH_3, breakeven pasture rental rates were $0.36, $0.50, and $0.65 per pound of gain for grain prices of $3, $5, and $7 per bushel, respectively. These estimated breakeven wheat pasture rental rates are the minimum rates that risk-neutral wheat producers would require to manage wheat to produce both fall-winter forage and grain and to lease the grazing rights to a livestock producer rather than producing wheat for grain-only.

For risk-averse wheat producers, these breakeven rates would be insufficient to entice a switch from grain-only to dual-purpose wheat production. Risk-averse producers would require a higher pasture rental rate before they would consider switching from grain-only to dual-purpose wheat. Pasture rental rates are highly dependent on the expected price of wheat grain and the cost of nitrogen fertilizer.

Wheat yield results from the varieties trial experiment in Marshall, OK show that a 7 bushel decrease in grain yield is expected from dual-purpose wheat due to an earlier planting date when compared to grain-only wheat. The expected grain yield from grain-only wheat was 40 bushels per acre, which is significantly greater ($P \leq 0.05$) than the grain yield of dual-purpose wheat of 33 bushels per acre. Steer gain per acre is expected to be 134 lbs per acre.

References

Archer, D.W. and Reicosky D.C. (2009). Economic Performance of Alternative Tillage Systems in the Northern Corn Belt. *Agronomy Journal*. 101, 296-304.

Doye, D. and Sahs, R. (2010). Oklahoma Pasture Rental Rates, 2010-2011. Current Report CR-216. Oklahoma Cooperative Extension Service, Stillwater.

Doye, D. and Sahs, R. (2009). Oklahoma Farm and Ranch Custom Rates, 2009-2010. Current Report CR-205. Oklahoma Cooperative Extension Service, Stillwater.

Doye, D. and Sahs, R. (2008). Oklahoma Pasture Rental Rates, 2008-2009. Current Report CR-216. Oklahoma Cooperative Extension Service, Stillwater.

Doye, D. and Sahs, R. (2006). Oklahoma Pasture Rental Rates, 2006-2007. Current Report CR-216. Oklahoma Cooperative Extension Service, Stillwater.

Doye, D. and Sahs, R. (2004). Oklahoma Pasture Rental Rates, 2004-2005. Current Report CR-216. Oklahoma Cooperative Extension Service, Stillwater.

Doye, D. and Sahs, R. (2002). Oklahoma Pasture Rental Rates, 2002-2003. Current Report CR-216. Oklahoma Cooperative Extension Service, Stillwater.

Doye, D. and Sahs, R. (2000). Oklahoma Pasture Rental Rates, 2000-2001. Current Report CR-216. Oklahoma Cooperative Extension Service, Stillwater.

Doye, D. and Sahs, R. (1998). Oklahoma Pasture Rental Rates, 1998-1999. Current Report CR-216. Oklahoma Cooperative Extension Service, Stillwater.

Doye, D. and Sahs, R. (1996). Oklahoma Pasture Rental Rates, 1996-1997. Current Report CR-216. Oklahoma Cooperative Extension Service, Stillwater.

Doye, D. and Sahs, R. (1993). Oklahoma Pasture Rental Rates, 1993-1994. Current Report CR-216. Oklahoma Cooperative Extension Service, Stillwater.

Doye, D. and Sahs, R. (1991). Oklahoma Pasture Rental Rates, 1991-1992. Current Report CR-216. Oklahoma Cooperative Extension Service, Stillwater.

Duke, J.C., Epplin, F.M., Vitale, J.D., and Peel, D.S. (2011). Forage plus grain wheat versus grain-only wheat. *Journal of the American Society of Farm Managers and Rural Appraisers.* 74, 33-41.

Edwards, J.T., Carver, B.F., Horn, G.W., and Payton, M.E. (2011). Impact of dual-purpose management on wheat grain yield. *Crop Science* 51, forthcoming.

Edwards, J.T. "Systems-based wheat management strategies", In *Wheat: Science and trade*, edited by B.F. Carver, 75-87. Wiley-Blackwell, Ames, IA., 2009.

Epplin, F.M., Hossain, I., and Krenzer, E.G. (2000). Winter wheat fall-winter forage yield and grain yield response to planting date in a dual-purpose system. *Agricultural Systems* 63, 161-173.

Epplin, F.M., Krenzer, E.G., and Horn, G. (2001). Net returns from dual-purpose wheat and grain-only wheat. *Journal of the American Society of Farm Managers and Rural Appraisers*. 65, 8-14.

Hardaker, J.B., Richardson, J.W., Lien, G., and Schumann, K.D. (2004). Stochastic efficiency analysis with risk aversion bounds: a simplified approach. *Australian Journal of Agricultural and Resource Economics* 48, 253–270.

Hardaker, J.B. and Lien, G. (2010). Stochastic efficiency analysis with risk aversion bounds: a comment. *Australian Journal of Agricultural and Resource Economics* 54, 379–383.

Heer, W.F., and Krenzer, E.G. (1989). Soil water availability for spring growth of winter wheat (*Triticum aestivum* L.) as influenced by early growth and tillage. *Soil Tillage Research* 14(2), 185-196.

Hossain, I., Epplin, F.M., and Krenzer, E.G. (2003). Planting date influence on dual-purpose winter wheat forage yield, grain yield, and test weight. *Agronomy Journal* 95, 1179-1188.

Hossain, I., Epplin, F.M., Horn, G.W., and Krenzer, E.G. (2004). Wheat Production and Management Practices Used by Oklahoma Grain and Livestock Producers. Oklahoma Agricultural Experiment Station Bulletin B-818.

Kaitibie, S., Epplin, F.M., Horn, G.W., Krenzer, E.G., and Paisley, S.I. (2003). Dual-Purpose Winter Wheat and Stocker Steer Grazing Experiments at the Wheat Pasture Research Unit, Marshall, Oklahoma. Oklahoma Agricultural Experiment Station Bulletin B-816.

Krenzer, E.G. "Introduction". In *Wheat management in Oklahoma. E-831*, edited by T.A. Royer and E.G. Krenzer, 1-4. Oklahoma State University Cooperative Extension Service, Stillwater, OK, 2000.

Krenzer, E.G. (1991). Wheat for pasture. Oklahoma State University Extension Facts 2586. Oklahoma State University Extension Service, Stillwater, OK.

Littell, R.C., Milliken, G.A., Stroup, W.W., and Wolfinger, R.D. (1996). SAS system for mixed models. SAS Institute, Cary, NC.

Lyon, D.J., Baltensperger, D.D., and Siles, M. (2001). Wheat grain and forage yields are affected by planting and harvest dates in the central great plains. *Crop Science* 41, 488-492.

Lyon, D.J., Nielsen, D.C., Felter, D.G., and Burgener, P.A. (2007). Choice of summer fallow replacement crops impacts subsequent winter wheat. *Agronomy Journal*. 99, 578-584.

Meyer, J., Richardson, J.W., and Schumann, K.D. (2009). Stochastic efficiency analysis with risk aversion bounds: a correction. *Australian Journal of Agricultural and Resource Economics* 53, 521–525.

Oklahoma Agricultural Statistics Service. (2010-1991). *Oklahoma Agricultural Statistics 2010-1991*. Oklahoma City, OK.

Piepho, H.P., Büchse, A., and Emrich, K. (2003). A hitchhiker's guide to mixed models for randomized experiments. *Journal of Agronomy and Crop Science*. 189, 310–322.

Richardson, J.W., Schumann, K., and Feldman, P. (2001). "Simulation for Excel to Analyze Risk." Department. Agricultural Economics Texas A&M University, College Station.

True, R., Epplin, F., Krenzer, Jr., E., and Bernardo, D. (2001). "A Survey of Wheat Production and Wheat Forage Use Practices in Oklahoma." Oklahoma State University Agricultural Experiment Station. Bull. No. B-815.

National Agricultural Statistics Service. (2011). *Oklahoma Quick Stats (Crops).* Available at http://www.nass.usda.gov/QuickStats/Create_Federal_All.jsp.

Williams, J.R., Llewelyn, R.V., Pendell, D.L., Schlegel, A., and Dumler, T. (2010). A risk analysis of converting Conservation Reserve Program acres to a wheat–sorghum–fallow rotation. *Agronomy Journal* 102, 612-622.

Table II-1. Historical wheat pasture rental rates, wheat prices, and cattle prices.

	Wheat Pasture rental rate	Wheat Price	Steer and Heifer Prices October Buy Price	February Sell Price
	$/lb. of gain	$/bushel	($/cwt)	($/cwt)
1991	0.31	2.85	82	87
1992		3.19	80	79
1993	0.31	2.94	84	85
1994		3.41	71	81
1995		4.41	61	72
1996	0.33	4.73	59	56
1997		3.21	75	68
1998	0.33	2.57	68	76
1999		2.24	78	73
2000	0.31	2.57	86	84
2001		2.74	85	88
2002	0.32	3.37	79	82
2003		3.31	100	78
2004	0.33	3.32	112	86
2005		3.39	113	102
2006	0.34	4.70	107	105
2007		6.22	109	97
2008	0.44	6.93	100	101
2009		4.89	89	89
2010	0.39	5.10		

Source: Doye and Sahs, 1991-2010. National Agricultural Statistics Service, 2011.

Oklahoma Agricultural Statistics Service, 1991-2010.

Table II-2. Mean wheat yield by management system by year in Marshall, Oklahoma (bushels/acre).

Year	Dual Purpose	Grain Only
1999	33	43
2000	44	42
2001	38	44
2002	45	49
2003	53	50
2004	39	51
2005	16	30
2006	22	28
2007	16	30
2008	56	64
2009	8	21
2010	44	36
2011	18	29
Average	33	40
Standard Deviation	7	8
F-Value	362.43	
P-Value	<.0001	

Source: Edwards et al., 2011.

Table II-3. Steer gain per acre by year at Marshall, Oklahoma (lbs./acre).

Year	Gain per acre
1990	123
1991	126
1992	94
1993	99
1994	199
1995	196
1996	0
1997	169
1998	163
1999	153
2000	149
Average	134
Standard Deviation	43

Source: Kaitibie et al., 2003.

Table II-4. Budgets for grain-only and dual-purpose wheat when wheat grain is $3 per bushel and the pasture rental rate is $0.30 per lb. of gain

Item	Unit of Measure	Price per unit	Grain Only Wheat Quantity	Grain Only Wheat Value	Dual Purpose Wheat Quantity	Dual Purpose Wheat Value
Production						
Wheat	Bu	$ 3.00	40	120.00	33	99.00
Beef Gain	lbs.	$ 0.30[a]			134	40.20
Gross Returns	acre			**$ 120**		**$ 139**
"Cash" Costs						
Wheat Seed	Bu.	$ 7.22	1	7.22	2	14.44
Anhydrous Ammonia (82-0-0)	Lbs.	$ 0.35	89	30.93	130	45.18
Fertilizer Application	acre	$ 9.00	1	9.00	1	9.00
DAP (18-46-0)	Lbs.	$ 0.34	50	16.75	50	16.75
Fertilizer Application	acre	$ 4.00	1	4.00	1	4.00
Herbicide (broadleaf)	acre	$ 3.50	0.75	2.63	0.75	2.63
Herbicide (grass)	acre	$ 10.31	1	10.31	1	10.31
Herbicide Application	acre	$ 5.00	1	5.00	1	5.00
Insecticide (e.g. dimethoate)	pint	$ 5.75	0.75	4.31	0.75	4.31
Foliar Fungicide (1 of 3 years)	acre	$ 19.70	0.33	6.50	0.33	6.50
Aerial Pesticide Application	acre	$ 5.00	1.33	6.65	1.33	6.65
Wheat Crop Insurance	acre	$ 7.00	1	7.00	1	7.00
Fuel	gallon	$ 3.35	4.92	16.48	4.92	16.48
Lube	acre			2.47		2.47
Repair	acre			7.12		7.12
Annual Operating Capital	$	$ 0.07	68.19	4.77	78.92	5.52
Wheat Custom Harvest & Haul						
Base Charge	acre	$ 20.00	1	20.00	1	20.00
Excess for > 20 bu./a	bu.	$ 0.20	20	4.00	13	2.60
Hauling	bu.	$ 0.20	40	8.00	33	6.60
Total "Cash" Costs	acre			**$ 173**		**$ 193**
Net Returns to Land, Machinery Fixed Costs, Labor, Overhead, and Management	acre			**$ (53)**		**$ (53)**

[a] The calculated wheat pasture lease price per pound of livestock weight gain at which the net returns to land, machinery fixed costs, labor, overhead, and management are equal for the grain-only and dual-purpose wheat production systems.

Table II-5. Budgets for grain-only and dual-purpose wheat when wheat grain is $5 per bushel and the pasture rental rate is $0.44 per lb. of gain

Item	Unit of Measure	Price per unit	Grain Only Wheat Quantity	Grain Only Wheat Value	Dual Purpose Wheat Quantity	Dual Purpose Wheat Value
Production						
Wheat	Bu	$ 5.00	40	200.00	33	165.00
Beef Gain	lbs.	$ 0.44 [a]			134	58.96
Gross Returns	acre			**$ 200**		**$ 224**
"Cash" Costs						
Wheat Seed	Bu.	$ 12.03	1	12.03	2	24.06
Anhydrous Ammonia (82-0-0)	Lbs.	$ 0.35	89	30.93	130	45.18
Fertilizer Application	acre	$ 9.00	1	9.00	1	9.00
DAP (18-46-0)	Lbs.	$ 0.34	50	16.75	50	16.75
Fertilizer Application	acre	$ 4.00	1	4.00	1	4.00
Herbicide (broadleaf)	acre	$ 3.50	0.75	2.63	0.75	2.63
Herbicide (grass)	acre	$ 10.31	1	10.31	1	10.31
Herbicide Application	acre	$ 5.00	1	5.00	1	5.00
Insecticide (e.g. dimethoate)	pint	$ 5.75	0.75	4.31	0.75	4.31
Foliar Fungicide (1 of 3 years)	acre	$ 19.70	0.33	6.50	0.33	6.50
Aerial Pesticide Application	acre	$ 5.00	1.33	6.65	1.33	6.65
Wheat Crop Insurance	acre	$ 7.00	1	7.00	1	7.00
Fuel	gallon	$ 3.35	4.92	16.48	4.92	16.48
Lube	acre			2.47		2.47
Repair	acre			7.12		7.12
Annual Operating Capital	$	$ 0.07	70.59	4.94	83.73	5.86
Wheat Custom Harvest & Haul						
Base Charge	acre	$ 20.00	1	20.00	1	20.00
Excess for > 20 bu./a	bu.	$ 0.20	20	4.00	13	2.60
Hauling	bu.	$ 0.20	40	8.00	33	6.60
Total "Cash" Costs	acre			**$ 178**		**$ 203**
Net Returns to Land, Machinery Fixed Costs, Labor, Overhead, and Management	acre			**$ 22**		**$ 21**

[a] The calculated wheat pasture lease price per pound of livestock weight gain at which the net returns to land, machinery fixed costs, labor, overhead, and management are equal for the grain-only and dual-purpose wheat production systems.

Table II-6. Budgets for grain-only and dual-purpose wheat when wheat grain is $7 per bushel and the pasture rental rate is $0.59 per lb. of gain

			Grain Only Wheat		Dual Purpose Wheat	
Item	Unit of Measure	Price per unit	Quantity	Value	Quantity	Value
Production						
Wheat	Bu	$ 7.00	40	280.00	33	231.00
Beef Gain	lbs.	$ 0.59 [a]			134	79.06
Gross Returns	acre			**$ 280**		**$ 310**
"Cash" Costs						
Wheat Seed	Bu.	$ 16.84	1	16.84	2	33.68
Anhydrous Ammonia (82-0-0)	Lbs.	$ 0.35	87	30.09	130	45.18
Fertilizer Application	acre	$ 9.00	1	9.00	1	9.00
DAP (18-46-0)	Lbs.	$ 0.34	50	16.75	50	16.75
Fertilizer Application	acre	$ 4.00	1	4.00	1	4.00
Herbicide (broadleaf)	acre	$ 3.50	0.75	2.63	0.75	2.63
Herbicide (grass)	acre	$ 10.31	1	10.31	1	10.31
Herbicide Application	acre	$ 5.00	1	5.00	1	5.00
Insecticide (e.g. dimethoate)	pint	$ 5.75	0.75	4.31	0.75	4.31
Foliar Fungicide (1 of 3 years)	acre	$ 19.70	0.33	6.50	0.33	6.50
Aerial Pesticide Application	acre	$ 5.00	1.33	6.65	1.33	6.65
Wheat Crop Insurance	acre	$ 7.00	1	7.00	1	7.00
Fuel	gallon	$ 3.35	4.92	16.48	4.92	16.48
Lube	acre			2.47		2.47
Repair	acre			7.12		7.12
Annual Operating Capital	$	$ 0.07	72.58	5.08	88.54	6.20
Wheat Custom Harvest & Haul						
Base Charge	acre	$ 20.00	1	20.00	1	20.00
Excess for > 20 bu./a	bu.	$ 0.20	20	4.00	13	2.60
Hauling	bu.	$ 0.20	40	8.00	33	6.60
Total "Cash" Costs	acre			**$ 182**		**$ 212**
Net Returns to Land, Machinery Fixed Costs, Labor, Overhead, and Management	acre			**$ 98**		**$ 98**

[a] The calculated wheat pasture lease price per pound of livestock weight gain at which the net returns to land, machinery fixed costs, labor, overhead, and management are equal for the grain-only and dual-purpose wheat production systems.

Table II-7. Pasture rental rate required for dual-purpose wheat to breakeven with grain-only wheat for three wheat prices and three anhydrous ammonia prices ($ per pound of gain).

Wheat Price ($/bu.)	Base Assumptions $0.35/ lb. NH_3	$0.17/ lb. NH_3	$0.52/ lb. NH_3
$3	$ 0.30	$ 0.25	$ 0.36
$5	$ 0.44	$ 0.39	$ 0.50
$7	$ 0.59	$ 0.53	$ 0.65

Table II-8. Net returns certainty equivalents and grain only wheat risk premiums by wheat system for five absolute risk aversion coefficients when wheat grain is $3 per bushel

	Absolute Risk Aversion Coefficients (ARAC)				
	0.0000	0.002	0.0040	0.006	0.008
	Certainty Equivalents ($ per acre)				
Grain Only	-52.85	-54.21	-55.54	-56.85	-58.13
Dual Purpose	-52.33	-54.44	-56.54	-58.65	-60.74
	Risk Premium Relative to grain-only wheat ($ per acre)				
Dual Purpose	0.52	-0.23	-1.00	-1.80	-2.61
	BE Rental Rate ($ per lb. of gain)				
Dual Purpose	0.30	0.30	0.31	0.31	0.32

Table II-9. Net returns certainty equivalents and grain only wheat risk premiums by wheat system for five absolute risk aversion coefficients when wheat grain is $5 per bushel

	Absolute Risk Aversion Coefficients (ARAC)				
	0.0000	0.002	0.0040	0.006	0.008
	Certainty Equivalents ($ per acre)				
Grain Only	22.40	18.18	14.10	10.17	6.37
Dual Purpose	23.22	16.95	10.71	4.57	-1.43
	Risk Premium Relative to grain-only wheat ($ per acre)				
Dual Purpose	0.83	-1.23	-3.39	-5.60	-7.80
	BE Rental Rate ($ per lb. of gain)				
Dual Purpose	0.43	0.45	0.47	0.48	0.50

Table II-10. Net returns certainty equivalents and grain only wheat risk premiums by wheat system for five absolute risk aversion coefficients when wheat grain is $7 per bushel

	Absolute Risk Aversion Coefficients (ARAC)				
	0.0000	0.002	0.0040	0.006	0.008
	Certainty Equivalents ($ per acre)				
Grain Only	97.65	89.03	80.82	73.04	65.67
Dual Purpose	98.77	86.11	73.63	61.58	50.16
	Risk Premium Relative to grain-only wheat ($ per acre)				
Dual Purpose	1.13	-2.92	-7.20	-11.46	-15.51
	BE Rental Rate ($ per lb. of gain)				
Dual Purpose	0.58	0.61	0.64	0.68	0.71

APPPENDIX

Introduction

The tillage and cropping systems study for which yield data were obtained for Paper I included several crop rotations using the three crops studied (cotton, wheat and grain sorghum) and both tillage practices (tilled and no-till). Four rotations were included: cotton, fallow, wheat, grain sorghum; cotton, fallow, wheat; cotton, grain sorghum; wheat, double cropped grain sorghum, cotton, fallow. The crop rotation data were not included in the first study as each crop in each rotation was not grown each year, which confounded the study due to year to year effects. Table A-1 shows the crops grown in each year of the study. Each crop in each rotation and tillage practice was not grown each year due to limited resources and land at the experiment station in Altus, OK. The experiment only had 42 plots available, which was only adequate for three reps of one crop in each rotation using NT and TL and for each of the continuous crops in both tillage systems. The experiment would require 90 plots to grow three reps of each crop of each rotation and each continuous crop in both tillage systems in each year. Conducting an experiment of this size was infeasible due to limited resources and land.

Rotation Yield Data

Yields for each rotation are summarized in Tables A-2, A-3, A-4, and A-5. These tables contain many blank observations because only one crop in the crop rotation was grown each year. Since only one crop of each rotation was grown each year, the crop rotation portion of the experiment was not included in Paper I.

Table A-1. Rotation Systems: Crops Grown Each Year

	Rotation Systems			
Year	C-F-W-GS	C-F-W	C-GS	W-DCGS-C-F
2003	Cotton	Cotton	Cotton	Wheat & Grain Sorghum
2004	Fallow	Fallow	Grain Sorghum	Cotton
2005	Wheat	Wheat	Cotton	Fallow
2006	Grain Sorghum	Cotton	Grain Sorghum	Wheat & Grain Sorghum
2007	Cotton	Fallow	Cotton	Cotton
2008	Fallow	Wheat	Grain Sorghum	Fallow

Table A-2. Mean yield of cotton, wheat, and grain sorghum for tilled and no-till production systems in a cotton-fallow-wheat-grain sorghum crop rotation by year on a Hollister silty clay loam soil.

	Units	2003	2004	2005	2006	2007	2008
Cotton Lint							
Intensive Till	kg ha^{-1} yr^{-1}	281				810	
No-Till	kg ha^{-1} yr^{-1}	297				911	
Cotton Seed							
Intensive Till	kg ha^{-1} yr^{-1}	481				1300	
No-Till	kg ha^{-1} yr^{-1}	471				1446	
Wheat Grain							
Intensive Till	kg ha^{-1} yr^{-1}			4323			
No-Till	kg ha^{-1} yr^{-1}			4952			
Grain Sorghum Grain							
Intensive Till	kg ha^{-1} yr^{-1}				0		
No-Till	kg ha^{-1} yr^{-1}				2552		

Table A-3. Mean yield of cotton, wheat, and grain sorghum for tilled and no-till production systems in a cotton-fallow-wheat crop rotation by year on a Hollister silty clay loam soil.

	Units	2003	2004	2005	2006	2007	2008
Cotton Lint							
Intensive Till	kg ha^{-1} yr^{-1}	378			0		
No-Till	kg ha^{-1} yr^{-1}	283			671		
Cotton Seed							
Intensive Till	kg ha^{-1} yr^{-1}	500			0		
No-Till	kg ha^{-1} yr^{-1}	463			1048		
Wheat Grain							
Intensive Till	kg ha^{-1} yr^{-1}	N/A		77			65
No-Till	kg ha^{-1} yr^{-1}	N/A		69			64

Table A-4. Mean yield of cotton, wheat, and grain sorghum for tilled and no-till production systems in a cotton-grain sorghum crop rotation by year on a Hollister silty clay loam soil.

	Units	2003	2004	2005	2006	2007	2008
Cotton Lint							
Intensive Till	kg ha^{-1} yr^{-1}	263		761		841	
No-Till	kg ha^{-1} yr^{-1}	291		752		832	
Cotton Seed							
Intensive Till	kg ha^{-1} yr^{-1}	440		1400		1337	
No-Till	kg ha^{-1} yr^{-1}	478		1368		1303	
Grain Sorghum Grain							
Intensive Till	kg ha^{-1} yr^{-1}		4234		0		1632
No-Till	kg ha^{-1} yr^{-1}		3487		4161		1881

Table A-5. Mean yield of cotton, wheat, and grain sorghum for tilled and no-till production systems in a wheat double cropped grain sorghum-cotton-fallow crop rotation by year on a Hollister silty clay loam soil.

	Units	2003	2004	2005	2006	2007	2008
Cotton Lint							
Intensive Till	kg ha^{-1} yr^{-1}		440			799	
No-Till	kg ha^{-1} yr^{-1}		499			936	
Cotton Seed							
Intensive Till	kg ha^{-1} yr^{-1}		718			1283	
No-Till	kg ha^{-1} yr^{-1}		810			1451	
Wheat Grain							
Intensive Till	kg ha^{-1} yr^{-1}	N/A			59		
No-Till	kg ha^{-1} yr^{-1}	N/A			0		
Grain Sorghum Grain							
Intensive Till	kg ha^{-1} yr^{-1}	1225			0		
No-Till	kg ha^{-1} yr^{-1}	1148			0		

VITA

Brandon Thomas Varner

Candidate for the Degree of

Master of Science

Thesis: NO-TILL VERSUS TILLED DRYLAND COTTON, GRAIN SORGHUM, AND WHEAT, AND BREAKEVEN PASTURE LEASE RATE FOR DUAL-PURPOSE WINTER WHEAT

Major Field: Agricultural Economics

Biographical:

Education:

Completed the requirements for the Master of Science in Agricultural Economics at Oklahoma State University, Stillwater, Oklahoma in December, 2011.

Completed the requirements for the Bachelor of Science in Agribusiness at Oklahoma State University, Stillwater, Oklahoma in 2009.

Experience:
Born and raised on a farm in Oklahoma; Graduate Research Assistant, Oklahoma State University, Department of Agricultural Economics, January 2010 to present.

Name: Brandon Thomas Varner Date of Degree: December, 2011

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: NO-TILL VERSUS TILLED DRYLAND COTTON, GRAIN SORGHUM, AND WHEAT, AND BREAKEVEN PASTURE LEASE RATE FOR DUAL-PURPOSE WINTER WHEAT

Pages in Study: 73 Candidate for the Degree of Master of Science

Major Field: Agricultural Economics

Scope and Method of Study: This study consisted of two papers. The research reported in the first paper was conducted to determine the optimal tillage and cropping system among three crops and two tillage systems. Yield data for cotton, grain sorghum, and wheat grown using no-till and tilled production practices were obtained from an experiment in southwest Oklahoma. Crop budgets were generated using the yield data and costs typical of the region for no-till and tilled systems. Net return distributions were subjected to risk analysis using stochastic efficiency with respect to a function.

The research reported in the second paper was conducted to determine the wheat pasture rental rate at which dual-purpose wheat would breakeven with grain-only wheat. Wheat yields and beef gain were obtained from experiments conducted at the Wheat Pasture Research Unit near Marshall, Oklahoma. Yield and beef gain data were used to generate budgets and determine the breakeven wheat pasture rental rate for dual-purpose and grain-only wheat for three levels of wheat grain price: \$3, \$5, and \$7 per bushel. Stochastic efficiency with respect to a function was used to compare net return distributions for dual-purpose wheat at varying levels of risk aversion.

Findings and Conclusions: In comparison of crops and tillage systems no-till wheat generated the greatest net return; however, due to the variability in net returns for the no-till system, tilled wheat was determine to be the most risk efficient system for risk averse producers. No-till may be a viable option for producers who can put the time saved in the no-till system to productive use elsewhere or to use the time saved to farm more acres.

The wheat pasture rental rate required for dual-purpose wheat to breakeven above cash costs (labor, machinery fixed costs, land, overhead, and management) with grain-only wheat is \$0.30, \$0.44, and \$0.59 per pound of gain for wheat grain prices of \$3, \$5, and \$7 per bushel. The breakeven pasture rental rate is sensitive to the price of wheat grain as well as to the price of nitrogen fertilizer.

ADVISER'S APPROVAL: Dr. Francis Epplin